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UNITED STATES DEPARTMENT OF AGRICULTURE

In Cooperation with the
Connecticut Agricultural Experiment Station

DEPARTMENT BULLETIN No. 1238

Washington, D. C. October 15, 1924

THE CANKERWORMS

By

B. A. PORTER, Entomologist, and
C. H. ALDEN, Scientific Assistant, Fruit Insect Investigations,
Bureau of Entomology

CONTENTS

WASHINGTON
GOVERNMENT PRINTING OFFICE
1924

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THE CANKERWORMS.[1]

By B. A. Porter, *Entomologist*, and C. H. Alden, *Scientific Assistant, Fruit Insect Investigations, Bureau of Entomology.*

CONTENTS.

INTRODUCTION.

The fall cankerworm (*Alsophila pometaria* Harris) and the spring cankerworm (*Paleacrita vernata* Peck) have been known in New England for more than two centuries, and in the Mississippi Valley for three-quarters of a century. The studies which form the basis of this bulletin were carried on at the laboratory maintained by the Bureau of Entomology at Wallingford, Conn., in cooperation with the Connecticut Agricultural Experiment Station at New Haven, for the study of insects affecting deciduous fruit trees. With the exception of one small isolated orchard which was badly infested with the spring cankerworm until the owners commenced spraying, neither species has been seriously abundant in the vicinity of Wallingford the past few years, although both were present in fair numbers.

The two species have much in common, and wherever possible they have been treated together.

[1] The work upon which this bulletin is based was done under the direction of Dr. A. L. Quaintance. The life-history work in connection with the spring species was carried on largely by the junior author; that on the fall form, for the most part by the senior author.

ECONOMIC HISTORY.

The cankerworms are among our oldest native pests, the record of their ravages beginning in colonial days. As early as 1661, one John Hull is said to have written that they had been abundant for four years. For the succeeding century and a quarter the record is very fragmentary, but, beginning with an outbreak occurring about 1790, it is possible to trace the successive outbreaks in considerable detail, although the accounts are often obscured by a lack of accurate information as to the identity of the species involved, and by accounts of local outbreaks occurring independently of the main fluctuations.

Among the premiums offered in 1793 by the Massachusetts Society for Promoting Agriculture were the following (*1*)[2]:

1. To the person who shall, on or before the first day of July, 1795, give a satisfactory natural history of the canker worm, through all of its transformations, at what depth in the ground, at what distance from the tree, and at what time they cover themselves; at what season, and in what form they rise from the ground; on what part of the tree they generally deposit their eggs, and at what time the eggs become worms; a premium of 50 dollars, or a piece of plate of that value, or the Society's gold medal, at the option of the author. If more than one satisfactory history should be given before the first of July, 1795, that first received by the Trustees will be entitled to the premium.
2. A premium of 100 dollars, to the person who shall, on or before the first day of July, 1796, discover an effectual, and the cheapest method of destroying the canker worm, and give evidence thereof to the satisfaction of the Trustees.

The first premium was secured in 1795 by William D. Peck (*2*), who described in considerable detail the life history and appearance of the different stages, chiefly of what we now know as the spring cankerworm, giving it the name *Phalaena vernata*. He noted, however, that some of the moths "rise" in November, doubtless referring to the fall species, although his figures were apparently all drawn from the spring form. A lesser prize was awarded to Noah Atwater (*3*), who also presented a good account of this pest. Peck's article was reprinted with some slight changes in 1796 in the Rules and Regulations of the Massachusetts Society for Promoting Agriculture (*4*). Parts of it have been reprinted a number of times since.

Before Peck's account appeared, the cankerworms had practically disappeared from New England, this being attributed to a freeze occurring in May, 1794, shortly after the larvæ had hatched. In 1801, the trustees (*5, p. 4*) of the Massachusetts society announced that "inasmuch as the cankerworm has in some places made its appearance again, it is judged proper to continue the premium for the most effectual and cheap method for its destruction." This outbreak was apparently not as severe as the previous one, because in the Agricultural Repository and Journal for June, 1815, J. Lowell (*6*) writes: "After having been freed for nearly twenty years from the ravages of the cankerworm * * * our orchards are again overrun with them." In this account, he says that the "insects rise in the fall," indicating that this particular outbreak consisted, to a great extent at least, of the fall species.

According to records made by Harris (*10*), the cankerworms were increasingly abundant in Massachusetts from 1831 to 1840, were not troublesome for the following six years, and were again on the increase from 1847 to 1854. Since that time numerous outbreaks have

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[2] Reference is made by number (italic) to "Literature cited," p. 36.

occurred at intervals in various parts of New England. In Connecticut, the "cankerworm years" have occurred during the following periods: 1838–1846, 1866, 1884, 1896–1900, and 1907–1909. The fall cankerworm seems to be on the increase at the present time (1921) in the State, although it is impossible to predict when the infestation will become severe enough to constitute an outbreak.

The history of the cankerworms in other sections of the country has been similar in many ways to that recorded for New England, consisting of successive outbreaks varying in extent and severity, alternating with periods of comparative scarcity.

In the Middle West, practically all records refer to the spring species. The history of the cankerworm in this section begins in 1852, with an outbreak in Illinois, which lasted from that date until 1860, in which year the worms suddenly disappeared. Severe outbreaks of the spring cankerworm have been reported at intervals in practically all States of the Mississippi Valley from Arkansas north.

Kansas has suffered outbreaks of the spring cankerworm during the periods 1879–1886, 1896–1899, and 1913–1917.

Both species have been known for many years in southern Canada, the fall form being most abundant and widespread, but the infestations in most cases do not seem to have been as severe as many of those occurring in the Mississippi Valley and in New England. The fall cankerworm has done considerable damage in Nova Scotia in recent years.

Neglected orchards in northern Virginia were badly infested by the spring species for several years previous to 1907 (*32*).

The fall cankerworm was reported from California in 1891, and later the spring species was also found. Since that time several outbreaks have occurred, and considerable damage has been done in the apple-growing regions of the central and northern parts of the State.

Local outbreaks of the fall species have been in progress in forest areas in the mountains of North Carolina since 1917, and a serious infestation of both species, the spring cankerworm especially, was reported from Wisconsin in 1921.

SCIENTIFIC HISTORY.

As already noted, the name given to "the" cankerworm by Peck in 1795 was *Phalaena vernata*, his description applying almost entirely to the spring form. In several accounts published between 1830 and 1841, the cankerworms were mentioned by Harris and others as *Geometra vernata*. In 1841, in his Report on the Insects of Massachusetts Injurious to Vegetation, Harris (*9, p. 333*) placed them in the genus Anisopteryx. At the same time he noted that two types of moths were found, and suggested that there might be two species involved. Should this be the case, he said, the latter may be called *Anisopteryx pometaria*, or the Anisopteryx of the orchard, while the former should retain the name originally given to it by Professor Peck.

More than 30 years elapsed before the existence of two species was generally recognized.

In 1862, Francis Walker (*11*) described two American species of Anisopteryx which he called *sericeiferata* and *restituens*. These

were later (*26*) shown to be synonyms of *vernata* Peck and *pometaria* Harris, respectively.

The two species were clearly distinguished in 1873, when Mann (*15*) indicated the differences between the adults of the two species, but owing to a lack of clearness in the language which had been used by Harris, he reversed the intended application of the specific names, calling the fall species *vernata* and the spring form *pometaria*. His attention was soon called to the error, and in a communication published January 1, 1874 (*16*), he corrected it, giving the specific names to the respective forms as we know them to-day. He also distributed a correction slip to be inserted with the original account. The following year, in his annual report for 1874, Riley (*17*) carried the distinction still further, differentiating between the two species in all stages, and illustrating the differences by figures. The same year he erected a new genus for *vernata* (*18*), and since that time the spring cankerworm has been generally known as *Paleacrita vernata* (Peck). In spite of the efforts made by Mann to correct his error, and in spite of the publication of Riley's account, the confusion caused by the misinterpretation of the language used by Harris persisted for several years, and in 1876 Packard (*19*) suggested for the fall species the name *autumnata* to replace *pometaria* Harris, which he thought had been applied by Harris to the spring species. This change was soon shown to be unnecessary.

The species *pometaria* was placed in the genus Alsophila by Hulst (*27*) in 1896, and since then no change has been made in nomenclature.

In 1901, Dyar (*29*) published detailed technical descriptions of the egg and larval stages of the fall cankerworm, and in 1902 (*30*) he published similar descriptions of the spring species.

SYNONYMY.

Paleacrita vernata (Peck).

Phalaena vernata Peck, 1795, *in* Mass. Mag., v. 7, Nos. 6 and 7, p. 323–327, 415–416.

Geometra vernata (Peck) Harris, 1830, *in* New England Farmer, v. 9, No. 1, p. 1–2.

Anisopteryx vernata (Peck) Harris, 1841, *in* Harris, Injurious Ins. Mass., p. 333.

Anisopteryx sericeiferata Walker, 1862, *in* Cat. Brit. Mus., pt. 26, p. 1697.

Paleacrita vernata (Peck) Riley, 1785, *in* Trans. Acad. Sci. St. Louis, v. 3, p. 573–577.

Alsophila pometaria (Harris).

Anisopteryx pometaria Harris, 1841, Injurious Ins. Mass., p. 333.

Anixopteryx restituens Walker, 1862, *in* Cat. Brit. Mus., pt. 26, p. 1696.

Alsophila pometaria (Harris) Hulst, *in* 1896, Trans. Amer. Ent. Soc., v. 23, Hayden), v. 10, p. 400.

Alsophila pometaria (Harris) Hulst, 1896, *in* Trans. Amer. Ent. Soc., v. 23, p. 257–258.

COMMON NAMES.

Cankerworms belong to that group of lepidopterous larvæ variously known as inchworms, measuring worms, spanworms, or loopers. The name cankerworm originated several centuries ago, and was used in Europe for a number of different species of caterpillars. In America the term cankerworm has been used for the most part in reference to the two species here discussed, although

it has been used to a limited extent for other species belonging to the same group. In recent years the two common species have been known respectively as the fall cankerworm (*Alsophila pometaria*) and the spring cankerworm (*Paleacrita vernata*), referring to their respective seasons of usual emergence.

DIFFERENCES BETWEEN THE SPECIES.

Table 1 gives briefly the most conspicuous differences by which the two species may be distinguished in all stages.

TABLE 1.—*Distinguishing characteristics of the fall and spring cankerworms.*

Stage.	Fall cankerworm.	Spring cankerworm.
Egg	Brownish gray, in the form of a flowerpot, laid in a compact, single-layered mass in exposed locations, chiefly in the fall.	Dull pearl, oval in shape, laid in loose clusters in protected places, almost exclusively in the spring.
Larva	A pair of rudimentary prolegs on the 5th abdominal segment.	No prolegs on the 5th abdominal segment.
Pupa	Enclosed in a tough cocoon, with particles of earth woven in with the silk.	No cocoon formed.
Adult	Abdomen without spines	Abdominal segments bearing double transverse rows of reddish spines.

FOOD PLANTS.

Both species of cankerworm seem to have a preference for apple and elm, but also feed on a wide range of food plants, including many of the common deciduous fruit and forest trees, particularly those included among the Rosaceae. The following list has been brought together from a number of sources; there has been no opportunity for verification of many of the records, but they are probably accurate for the most part.

Both species have been recorded as feeding on the following hosts:

Acer spp	Maple.
Acer negundo L	Boxelder.
Acer saccharinum L	Silver maple.
Betula spp	Birch.
Carya spp	Hickory.
Castanea dentata (Marsh.) Borkh	American chestnut.
Celtis occidentalis L	Hackberry.
Crataegus spp	Haw.
Cydonia oblonga Mill	Quince.
Fraxinus sp	Ash.
Juglans nigra L	Black walnut.
Prunus armeniaca L	Apricot.
Amygdalus persica L	Peach.
Prunus domestica galatensis Hort	Prune.
Pyrus communis L	Pear.
Malus sylvestris Mill	Apple.
Quercus spp	Oak.
Salix spp	Willow.
Tilia americana L	American linden.
Ulmus americana L	American elm.

In addition to the host plants already noted, the spring cankerworm has been recorded as feeding on the following hosts:

Betula alba L.	European white birch.
Hicoria glabra (Mill.) Britton	Pignut.
Hicoria ovata (Mill.) Britton	Shagbark hickory.
Catalpa speciosa Warder	Western catalpa.
Fraxinus americana L.	White ash.
Fraximus nigra Marsh	Black ash.
Gleditsia triacanthos L.	Honey locust.
Ligustrum vulgare L.	Privet.
Prunus cerasus L.	Sour cherry.
Prunus pensylvanica L. f.	Pin cherry.
Prunus domestica L.	Plum.
Pyrus ioensis (Wood) Britton	Prairie crab.
Quercus macrocarpa Michx.	Mossycup oak.
Quercus muhlenbergii Engelm.	Chinquapin oak.
Quercus palustris DuRoi	Pin oak.
Quercus borealis maxima (Marsh.) Ashe	Red oak.
Rosa setigera Michx.	Prairie rose.
Rosa spp.	Roses, cultivated varieties.

In addition to the host plants listed as common to both species, the following have been recorded for the fall cankerworm:

Juglans cinerea L.	Butternut.
Prunus avium L.	Mazzard.
Prunus serotina Ehrh.	Black cherry.

DISTRIBUTION.

It has been difficult to determine from the literature the exact limits of the distribution of the respective cankerworms, since many accounts are indefinite as to the identity of the species under consideration. The approximate distribution of the two species is shown in the maps (figs. 1, 2) and is as follows:

FALL CANKERWORM.

The fall cankerworm occurs in the northeastern United States from North Carolina, Kentucky, and Missouri northward into southern Canada as far west as Manitoba, and along the northern border of the United States through the States of Minnesota, North Dakota, and Montana. It has also been reported from Colorado and California.

SPRING CANKERWORM.

The spring species is found throughout the northeastern and north-central part of the United States. It has been reported in the extreme southern part of Canada from Nova Scotia to Lake Huron, and also in Manitoba. The western limit of the main area of infestation seems to be Manitoba, Minnesota, Nebraska, Colorado, and Oklahoma. It has been recorded as far south as Jacksonville, Tex.; Arkansas, Tennessee, and North Carolina. It has also been found in California.

MEANS OF DISSEMINATION.

Owing to the wingless condition of the female moths, the natural spread of the cankerworms is very slow. This accounts for the occurrence of isolated infestations and their slowness in extending over additional territory. The cankerworms are carried to new localities largely by three methods. (1) The tiny recently hatched larvæ often spin down on threads and are blown about by the wind. The

greatest distance to which they may be blown in this manner does not seem to have been demonstrated, but they are doubtless blown at least from tree to tree. (2) The larger larvæ also suspend themselves by threads and some of them are often caught on passing vehicles and transported to new localities. (3) The egg masses, particularly of the fall species, which winters in this condition, are frequently car-

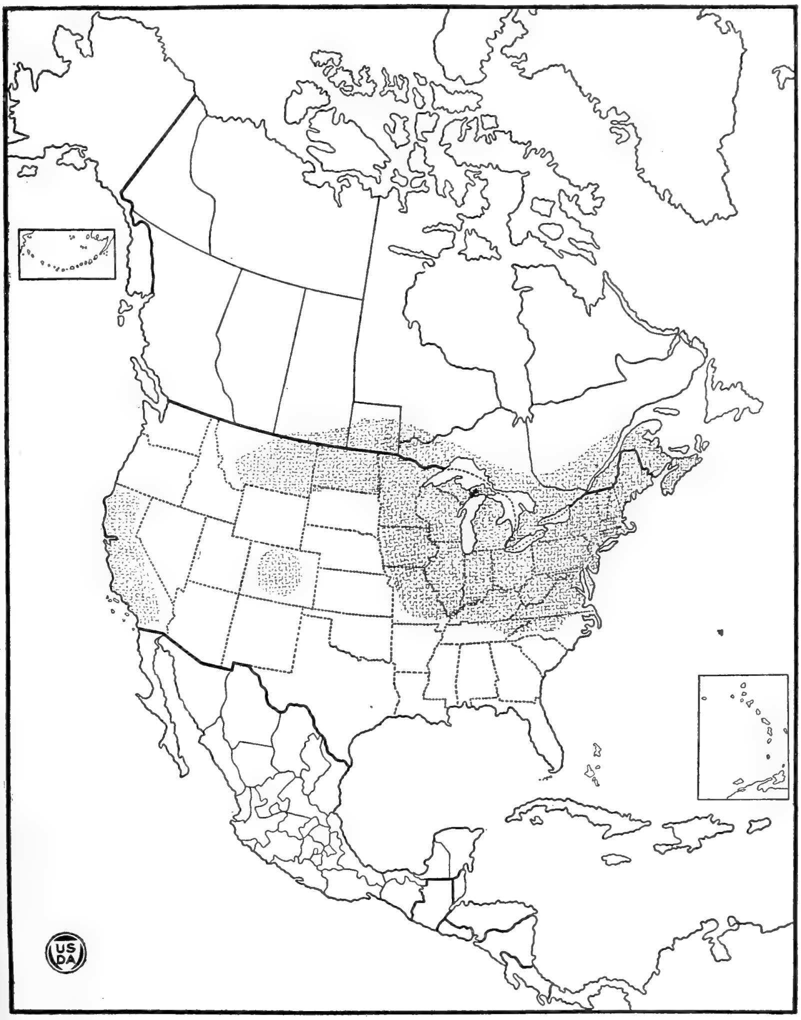


FIG. 1.—Distribution of the fall cankerworm.

ried to uninfested territory on nursery stock. In 1911 egg masses of the fall cankerworm were found in British Columbia on nursery stock imported from the United States (*34*). The clusters of eggs are easily overlooked, and doubtless many of them have been transported to other localities where the cankerworm had been hitherto unknown.

ECONOMIC IMPORTANCE.

During periods of abundance enormous damage is done by one or the other species of cankerworm, or by both working together. When especially abundant, the larvæ defoliate the trees, leaving only the midribs and larger veins of the leaves with a few ragged shreds of

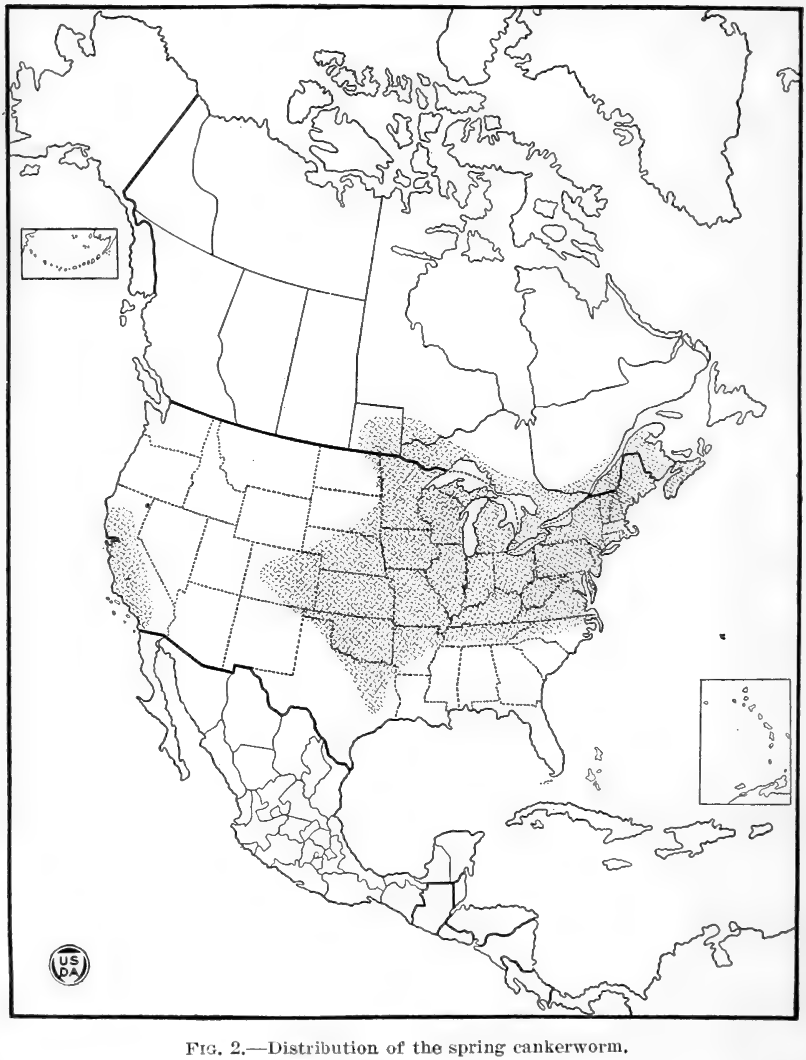
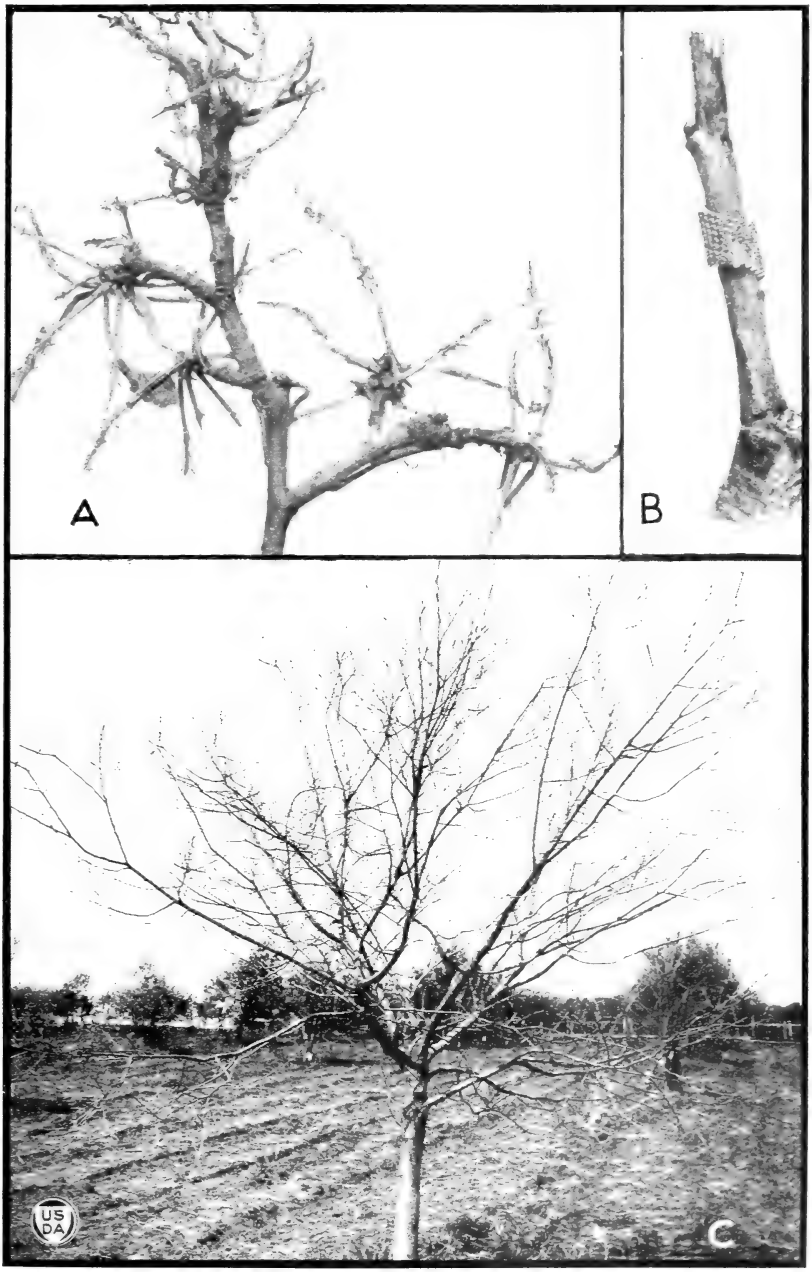


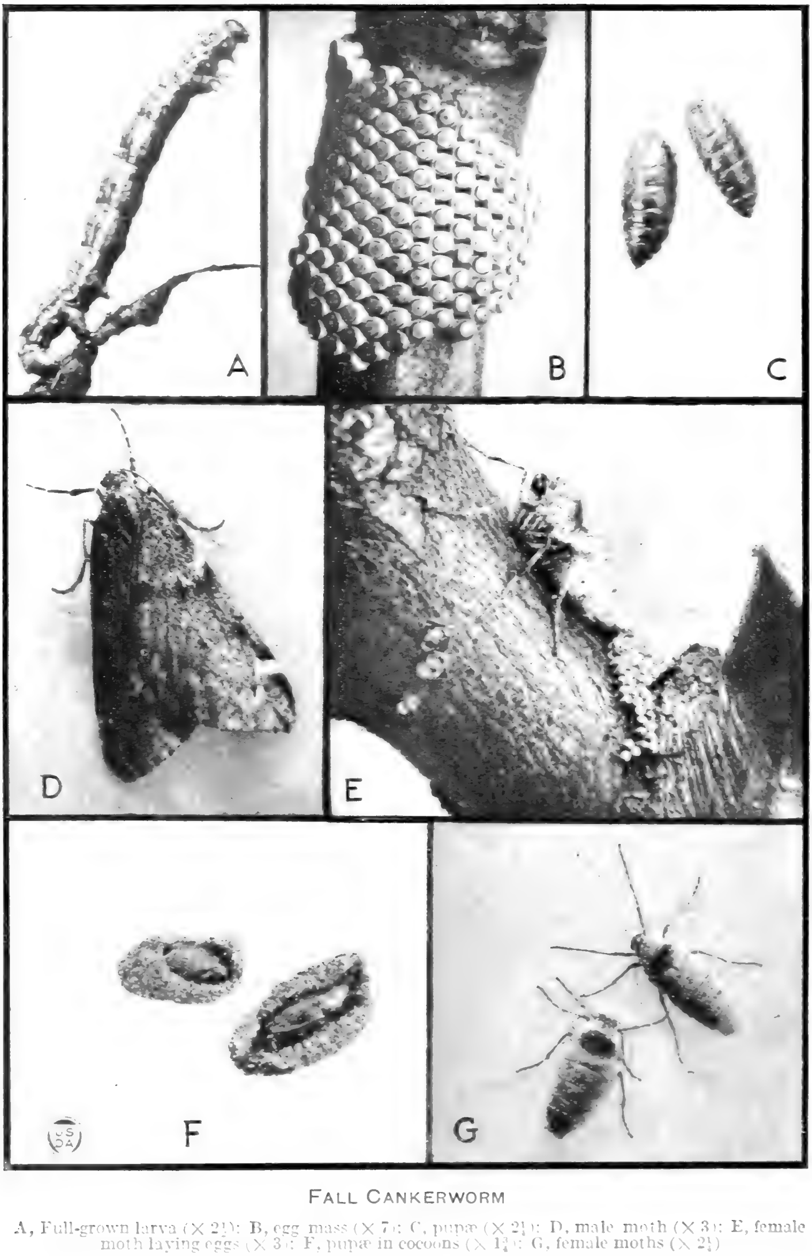
FIG. 2.—Distribution of the spring cankerworm.

leaf tissue. (Pl. I, A, C.) When the worms are somewhat less abundant, the leaves may not be entirely consumed, but many of them turn brown and dry. In either case, the trees are badly weakened, and, if defoliated for several years in succession, are likely to be killed. Young orchards not in bearing, which are often not tho-oughly sprayed, neglected orchards, and unprotected shade trees



CANKERWORMS

A, Apple twig defoliated by cankerworms; B, egg mass of fall cankerworm; C, young apple tree defoliated by cankerworms



FALL CANKERWORM

A, Full-grown larva ($\times 2\frac{1}{2}$); B, egg mass ($\times 7$); C, pupæ ($\times 2\frac{1}{4}$); D, male moth ($\times 3$); E, female moth laying eggs ($\times 3$); F, pupæ in cocoons ($\times 1\frac{3}{4}$); G, female moths ($\times 2\frac{1}{4}$)

suffer the most severe losses. In orchards which are well cared for and consistently sprayed with arsenicals, there is little opportunity for the cankerworms to gain a foothold. Such orchards are usually comparatively immune from attack, even during a period when cankerworms are abundant in the immediate neighborhood. As far as orchards are concerned, the cankerworm may therefore be rated as a pest which may be easily controlled, but which during periods of abundance may do serious damage if the orchards are neglected. As a shade-tree pest, the cankerworm is periodically of great importance.

FALL CANKERWORM.

DESCRIPTIONS.

EGG MASS.

Counts were made at Wallingford, Conn., of the number of eggs in 35 egg masses collected in the field in 1919 and 1920 and 76 egg masses laid in captivity in the fall of 1919. In the field-collected eggs the maximum number in a mass was 244, the minimum 3, and the average 129.3; in those laid in captivity the maximum was 408, the minimum 4, and the average 101.2. Thus the number of eggs in a single egg mass is seen to vary from a very few to several hundred, although the largest masses probably resulted from the efforts of more than one moth. The largest cluster noted, that of 408 eggs, is known to have been contributed to by two females.

Britton (*33*) reports for 100 egg masses collected in the field an average of 94 eggs, and for 65 laid in captivity an average of 148.

The eggs are laid in various places, but usually on the smaller branches and twigs, frequently very near the tips. The moths have been known to deposit their eggs on fence posts and the sides of houses. The masses are often found on tree trunks, especially if a barrier has interrupted the progress of the moth. On a tree trunk or other nearly flat surface, they form a flat mass; on a very small twig the cluster is cylindrical, frequently encircling the twig completely (Pl. I, B; II, B). The eggs are laid in straight rows following the length of the twig, each egg opposite the space between two eggs in the adjacent row, and are placed so closely together that their natural circular outline frequently becomes slightly hexagonal where they come in contact at the top.

The individual egg is somewhat cylindrical, rounded at the base, and smaller at the base than at the top, which is slightly convex with a small pit at the center. Measurements of a number of eggs from several different masses averaged as follows: Height 0.70 millimeter, width at top 0.50 millimeter, width at base 0.42 millimeter. In general color the egg is an ashy gray which is lightest at the base and on the sides. The greater part of the top, or cap, of the egg is a darker gray to brown, having near the outer edge a depressed circle within which is a narrow circle of brown. The surface of the cap of the egg is very minutely and irregularly sculptured, with a few of these fine lines radiating in an irregular fashion from the central depression.

LARVA.

First stage.—Width of head 0.36 to 0.39 millimeter, average 0.37 millimeter; length when newly hatched 1.84 millimeters, when full-fed about 4.5 millimeters. General color of newly hatched larva yellowish green to olive green. Head

much wider than the rest of the body, yellowish green to yellowish brown with a narrow posterior margin of brown. Thoracic shield varying from much the same color as the head to olive green, lighter anteriorly. Thorax and abdomen yellowish green to olive green, dorsum with a median longitudinal darker stripe. Between the dorsal and lateral rows of tubercles is a much narrower longitudinal dark line. Tubercles pale, with a dark green spot in the center of each. Anal segment light green.

Ventral surface lighter green than dorsal. Legs about concolorous with the ventral surface, dusky at the tips. Three pairs of prolegs: A very small pair on the fifth abdominal segment, and larger ones on the sixth and anal segments. Hairs very short and sparse.

When full fed, the larvæ become a lighter green with narrow longitudinal pale lines, which become more distinct in the next instar.

Second stage.—Width of head 0.61 to 0.66 millimeter, average 0.64 millimeter, length when full fed about 8 millimeters. General color green, varying from pale yellowish green to very dark green. Individuals from the same egg cluster often show wide variations in color. Head light green with varying areas of dusky green; in very dark specimens the head becomes almost entirely dark green. The middle of the dorsal surface of the body has a darker longitudinal stripe, which usually does not extend far into the anal segment. On each side of this median stripe is a pair of light, narrow, longitudinal lines; and below the spiracles, following the folds of the integument, an irregular light line. Tubercles concolorous with the surrounding surface, except for a dark dot in the center. Spiracles dark-margined. Ventral surface varying from light to dark green with a lighter median area.

Third stage.—Width of head 1.05 to 1.13 millimeters, average 1.09 millimeters; length when full fed 14 to 15 millimeters. General color green, varying from pale to very dark, almost black. Larvæ reared in battery jars in the insectary averaged much darker in color than those in the same stage collected in the field. Head varying from pale green to very dark, almost black; sometimes a mottled mixture of light and dark green. Markings similar to those described in the previous instar. On each side of the median dorsal stripe is a pair of light longitudinal lines, and in the dorsal area there is frequently a faint suggestion of a third pair of lines. Below the spiracles a broader irregular light line follows the folds of the integument. In some individuals, especially the lighter colored ones, the pale longitudinal lines become more or less partial, being broken and interrupted. Anal segment sometimes mottled with a very dark green. Spiracles dark-margined. Ventral surface lighter in color than the dorsal, usually with the median longitudinal portion lighter still.

Fourth stage (Pl. II, A).—Width of head 1.65 to 1.93 millimeters, average 1.77 millimeters; length when full fed and ready to enter the ground 20 to 27 millimeters. General color, as in previous instars, very variable, ranging from very light green to very dark and sometimes brownish green. Head and anal segment varying from a very pale to darker green, sometimes mottled with black, sometimes almost entirely black. In light-colored individuals the head is frequently mottled with areas of creamy white. Body markings as described in previous instar, with further variations. The dorsal area frequently has in it faint suggestions of additional light longitudinal lines. Some of the lighter colored larvæ have a series of irregular splotches of black behind each spiracle, that on the prothorax extending in front of the spiracle; in other larvæ some of these dark spots are present and others missing. Some light-colored individuals have darker markings dorsally on the prothorax and on the seventh and eighth abdominal segments. The light longitudinal lines frequently have a yellowish tinge, and in rare cases a reddish brown color. Other variations doubtless occur. Spiracles margined with dark brown. Ventral surface pale green, even in darker specimens, lighter in color along the median line, and sometimes with a pair of faint, interrupted, light, longitudinal lines on the outer edge.

COCOON.

Broadly oval in shape, 10 to 13 millimeters in length, with particles of grit and soil woven in with the silk. The cocoon is very tough, so much so that it is difficult to open without injury to the larva or pupa within (Pl. II, F).

Previous to pupation, the larva lies doubled within the cocoon.

PUPA.

Stout, 7 to 10 millimeters long. General color greenish brown, wing pads more greenish, margins of the segments a deeper brown. Surface without spines, somewhat finely punctate. Anal segment with a stout curved spine, terminating in a pair of curved bristles (Pl. II, C, F).

MOTH.

The following description has been condensed from Riley (*24*):

Male (Pl. II, D).—Expanse of wings 26 to 34 mm. Palpi rudimentary with joints indistinguishable. Antennae with over 50 joints, the longest not twice as long as wide, each with one pair of fascicles of slightly curled hairs. Abdomen without spines. Wings less transparent, more glossy than those of *P. vernata*, not striate, the scales on the average longer and more firmly attached. Upper surface of front wings brownish gray, but somewhat darker, with a purplish reflection, crossed with two jagged, whitish bands, the outermost suddenly bending inward near costa, where it forms a pale, quadrate spot, relieved by a darker shading of the wing around it; the bands sometimes so obsolete as to leave only this pale spot; but more often relieved on the sides towards each other by a dark shade, most persistent on the veins. Hind wings grayish brown, with a faint blackish discal dot. In most specimens a curved white band runs across the wing, and the veins inside this band and on the hind border are generally dotted. Under surface with a dusky discal spot on each wing, and with the outer pale band on upper surface of front wings as well as that of the hind wings showing distinctly, the former relieved by a dusky spot inside at costa.

Female (Pl. II, E, G).—Length 6 to 10 mm. Antennae with over 50 joints, the longest hardly longer than broad; uniform in diameter, without pubescence. Body and legs smooth, clothed with glistening brown and white truncate scales intermixed, giving it an appearance of uniform, shiny, dark ash gray, somewhat paler beneath. Abdomen tapering rather bluntly behind, without spines.

SEASONAL HISTORY AND HABITS.

The following observations, recorded largely in the insectary, were carefully compared with field conditions, and were found to agree very closely.

EMBRYONIC DEVELOPMENT.

The development of the larva within the egg is apparently not completed until a few days previous to hatching. When fully developed, the larva lies doubled, with head and anal extremity near together just beneath the cap of the egg.

HATCHING OF THE EGGS.

In the vicinity of Wallingford, Conn., in a normal season, the eggs hatch early in May, beginning as the apple blossoms of midseason varieties are showing pink, and ending before they have opened. In 1918 hatching began May 4; in 1919 on May 1; in 1920, which was a very cold and late season, on May 11, and in 1921, an abnormally early season, on April 16. The relation between the stage of development of the apple buds and the hatching of the cankerworms was approximately the same each year. Hatching in a given locality may extend over a period of 12 days, depending on weather conditions, but ordinarily the greater part of it occurs within 4 or 5 days. With individual egg clusters, most of the hatching is completed within 2 or 3 days after the first egg hatches.

Table 2 gives a summary of the hatching records of 31 egg masses collected in the field in 1919 and 6 egg masses collected in 1920.

TABLE 2.—*Hatching of eggs of the fall cankerworm from egg masses collected in the field, Wallingford, Conn., 1919 and 1920.*

Date.	Number of eggs hatched	Temperature.			Date.	Number of eggs hatched	Temperature.		
		Maximum.	Minimum.	Average.[1]			Maximum.	Minimum.	Average.[1]
FROM 31 EGG MASSES, 1919.									
		° F.	° F.	° F.			° F.	° F.	° F.
May 1	226	54	38	46.5	May 7	378	54	45	50.1
May 2	152	70	45	57.4	May 8	48	78	52	62.0
May 3	200	73	48	58.1	May 9	2	52	47	50.5
May 4	833	77	47	61.4	May 10	2	47	40	42.6
May 5	1,003	89	52	65.2	May 11	1	48	41	44.0
May 6	599	66	43	53.0	May 12	1	50	42	46.0
FROM 6 EGG MASSES, 1920.									
May 11	150	66	49	54.7	May 15	28	64	46	54.8
May 12	190	66	44	56.0	May 16	12	71	43	58.1
May 13	168	57	47	50.5	May 17	20	74	47	60.6
May 14	88	54	45	48.7					

[1] This column represents the average of hourly temperatures recorded by the thermograph.

In hatching, the larva gnaws a hole in the cap of the egg, usually including most of the area within the dark circle. Sometimes the hole is eaten out nearly round, but more often a small segment of the circle is left at one side. The opening through which the larva will emerge is about two-thirds the width of the head, so that in leaving the egg, the larva usually tips its head and works it through sideways.

In many cases, for some unknown reason, quite a proportion of the eggs failed to hatch. In 1920 five egg clusters, collected in the field a short time before hatching, gave only about 53 per cent of the possible number of larvæ. None of these egg masses were parasitized.

HABITS OF THE LARVÆ.

The newly hatched larvæ make their way to the unfolding leaves and buds and commence feeding. At first they gnaw small pits in either surface of the leaves, but they soon eat all the way through, making small perforations here and there. The younger larvæ seem to have a preference for the young, tender, newly formed leaves, and do most of their feeding near the tips of the rapidly growing shoots. When the larvæ are numerous, the leaves may be skeletonized, little being left except the veins and shreds of leaf tissue.

After the first instar, larger and larger irregular holes are made in the leaves, and when the larvæ are nearly full grown, they may consume almost entire leaves, leaving only the midribs and larger veins with a few ragged shreds of leaf tissue. Unless the larvæ are numerous, however, the feeding is not likely to be very conspicuous, as they have a strong tendency to wander, consuming a little here and there as they go. The worms also feed occasionally in the blossoms.

When disturbed, many of the larvæ drop suspended on threads. Those remaining on the leaves are often hard to find, because of their similarity in color to the leaves.

NUMBER OF LARVAL STAGES.

Some writers have reported five larval stages for the fall cankerworm, but all larvæ under observation at Wallingford have invariably entered the ground at the close of the fourth instar.

LENGTH OF FEEDING PERIOD.

Table 3 gives the larval feeding period for 165 larvæ from 6 egg masses in 1919 and for 106 larvæ from 5 egg masses in 1920. These data are summarized in Table 4, in which it will be noted that a larva may complete its development in as short a time as four weeks, or it may require nearly six. Practically all of them, however, completed their feeding in from 30 to 35 days, and in both seasons the average was slightly over 32 days.

TABLE 3.—*Length of larval feeding period of the fall cankerworm, Wallingford, Conn., 1919 and 1920.*

FOR 165 LARVÆ FROM 6 EGG MASSES, 1919.

Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.	Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.
May 1	June 1	1	31	May 4	June 7	3	34
Do	June 2	2	32	Do	June 8	1	35
Do	June 3	6	33	Do	June 10	2	37
Do	June 4	1	34	Do	June 11	1	38
Do	June 7	1	37	May 5	June 4	6	30
May 2	June 3	7	32	Do	June 5	8	31
Do	June 4	7	33	Do	June 6	26	32
Do	June 5	2	34	Do	June 7	2	33
May 3	June 4	4	32	May 6	June 5	7	30
Do	June 6	1	34	Do	June 6	16	31
Do	June 7	3	35	Do	June 7	5	32
May 4	June 1	1	28	Do	June 9	2	34
Do	June 3	1	30	Do	June 10	1	35
Do	June 4	8	31	May 7	June 6	2	30
Do	June 5	21	32	Do	June 10	1	34
Do	June 6	16	33				

FOR 106 LARVÆ FROM 5 EGG MASSES, 1920.

Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.	Date of hatching.	Date entered soil.	Number of larvæ.	Number of days.
May 11	June 10	2	30	May 13	June 16	1	34
Do	June 11	13	31	Do	June 17	1	35
Do	June 12	4	32	Do	June 19	1	37
Do	June 14	2	34	Do	June 20	1	38
Do	June 15	3	35	Do	June 23	1	41
May 12	June 12	1	31	May 14	June 14	5	31
Do	June 13	4	32	Do	June 15	3	32
Do	June 14	6	33	May 15	June 15	3	31
Do	June 15	7	34	Do	June 16	1	32
Do	June 16	1	35	May 16	June 16	2	31
Do	June 20	1	39	Do	June 18	1	33
May 13	June 12	14	30	Do	June 23	2	38
Do	June 13	10	31	May 17	June 16	1	30
Do	June 14	6	32	Do	June 19	1	33
Do	June 15	7	33	Do	June 22	1	36

TABLE 4.—*Length of larval feeding period of fall cankerworm, Wallingford, Conn., 1919 and 1920. Summary of Table 3.*

Number of days.	Number of larvæ.	
	In 1919.	In 1920.
28	1	0
29	0	0
30	16	17
31	33	34
32	65	18
33	31	15
34	10	10
35	5	5
36	0	1
37	3	1
38	1	3
39	0	1
40	0	0
41	0	1
Total	165	106
Average length of feeding period in days	32.1	32.2

Table 5 records observations on the average length of the different larval stages of the fall cankerworm at Wallingford during 1919 and 1920.

TABLE 5.—*Average length of larval stages of fall cankerworm, Wallingford, Conn., 1919 and 1920.*

Stage.	1919		1920	
	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.
First	255	13.27	127	11.18
Second	213	5.85	115	5.38
Third	195	5.13	112	5.21
Fourth (to end of feeding)	165	7.94	106	10.51
Total	....	32.2	....	32.3

It will be noted that the total larval feeding period in Table 5 differs slightly from that given in Table 4, which is based only on those larvæ completing their development, while the data in Table 5 are based on different numbers of larvæ in the successive stages.

ENTERING THE GROUND.

For cocooning and pupation the larvæ enter the ground to a depth of several inches. In battery jars containing about 6 inches of loose soil, they go down about 2½ inches. In the field the depth varies according to soil conditions.

To all external appearances the cocoon is complete about 24 hours after the larva has entered the soil, although in some cases its construction may take 48 hours.

Table 6 shows the dates the larvæ entered the soil in 1919 and 1920. On June 25, 1920, two days after the last larva under observation in the insectary at Wallingford had entered the ground, several larvæ were noted at Milford, Conn., about 24 miles southwest of Walling-

ford, which were still feeding, but were apparently full grown and about on the point of leaving the tree. With this one exception, the data in the table agree with observations made in the field.

TABLE 6.—*Entrance into ground of larvæ of the fall cankerworm, Wallingford, Conn., 1919 and 1920.*

In 1919.				In 1920.			
Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.	Date.	Number of larvæ.
June 1	2	June 8	1	June 10	2	June 18	1
June 2	2	June 9	2	June 11	13	June 19	2
June 3	14	June 10	4	June 12	19	June 20	2
June 4	26	June 11	1	June 13	14	June 21	0
June 5	38			June 14	19	June 22	1
June 6	61	Total	165	June 15	23	June 23	3
June 7	14			June 16	6		
				June 17	1	Total	106

PREPUPAL PERIOD.

It is impossible to determine by daily examination the exact length of the prepupal period, due to the toughness of the cocoon, which makes it difficult to avoid injuring the larva while opening the cocoon for examination. The approximate period, however, was ascertained as follows: A number of larvæ were allowed to enter soil in battery jars and construct their cocoons, which were then sifted out and placed in soil in flowerpots sunk in the ground in the insectary yard. At intervals a number of cocoons were dug up, examined, and the number of larvæ and pupæ recorded. After having been disturbed, and very possibly injured, these individuals were not used for further records, but a fresh lot was used each time. The results of these examinations were as follows: Up to and including the twenty-sixth day none had pupated; on the twenty-seventh day a few pupæ were found; on the thirtieth day half or more of them had transformed, and on the thirty-fourth and thirty-fifth days four-fifths of them had pupated. Taking into consideration the possibility that due to disease, parasites, or injury, a certain proportion of the larvæ might never have pupated, it seems likely that practically all pupation takes place in 27 to 35 days, with the average prepupal period falling between 31 and 32 days for the normal season.

EMERGENCE OF MOTHS.

The moths may begin to emerge at any time in the fall, but do not usually leave the ground in numbers until freezing weather has occurred. In 1919 the lowest temperature previous to the first emergence was 32° F.; in 1920 the lowest was 37° F. In 1919 the lowest temperature preceding emergence in numbers was 26° F., on November 10, but a much greater emergence followed a minimum temperature of 20° F., on the 16th. In 1920 the first period of emergence in numbers began on November 18, after temperatures of 19° F. on the 13th and 21° F. on the 14th. The maximum emergence followed after a minimum temperature of 24° F. on the night of November 29.

Table 7 gives data relative to the emergence of moths in 1919 and 1920. These data include records from two sources. In a few of the cages nearly full-grown larvæ collected in the field were allowed to complete their feeding and enter the soil normally; the material in the other soil cages was transferred after having entered soil and spun cocoons in battery-jar cages in the insectary. Emergence occurred over approximately the same periods for both classes of material, the peaks of the emergence coinciding exactly, and as a matter of convenience the records are here combined in one table.

With the material collected in the field and allowed to enter the soil normally, it is not known exactly how many completed their feeding, entered the soil, cocooned, and pupated.

Out of 157 cocoons placed in the soil cages in 1919, 90 moths, or 57 per cent of the possible total, emerged. The following year 247 moths emerged from 312 cocoons, or 79 per cent of the possible total.

TABLE 7.—*Emergence of moths of the fall cankerworm, Wallingford, Conn., 1919 and 1920.*

IN 1919.

Date.	Emergence.		Temperature.			Remarks.
	Male.	Female.	Minimum.	Maximum.	Average.	
			°F.	°F.	°F.	
Nov. 2	....	1	35	62	47.5	Rain.
Nov. 3	....	3	29	51	39.1	Clear.
Nov. 4	....	4	36	51	43.8	Cloudy.
Nov. 5	....	3	37	46	40.8	Rain.
Nov. 6	....	0	37	45	39.4	Clear.
Nov. 7	....	0	34	45	39.2	Do.
Nov. 8	....	0	31	51	38.4	Do.
Nov. 9	....	1	27	55	36.8	Do.
Nov. 10	....	0	26	59	37.8	Do.
Nov. 11	....	19	32	50	43.4	Light rain.
Nov. 12	....	3	48	57	52.4	Rain.
Nov. 13	....	0	31	55	43.3	Do.
Nov. 14	....	1	27	47	33.7	Clear.
Nov. 15	....	0	24	44	32.5	Do.
Nov. 16	1	9	20	49	34.7	Do.
Nov. 17	1	69	35	54	43.2	Do.
Nov. 18	....	21	33	58	44.0	Do.
Nov. 19	....	0	25	40	33.9	Do.
Nov. 20	....	0	20	32	24.9	Do.
Nov. 21	....	0	20	51	35.2	Do.
Nov. 22	....	13	39	51	44.5	Do.
Nov. 23	....	2	33	51	40.6	Do.
Nov. 24	....	1	30	49	36.8	Do.
Nov. 25	....	0	28	49	40.5	Do.
Nov. 26	....	0	37	48	44.2	Rain.
Nov. 27	....	0	31	42	37.2	Do.
Nov. 28	....	0	28	33	30.3	Cloudy.
Nov. 29	....	1	32	58	42.4	Rain.
Nov. 30	....	0	31	59	49.2	Clear.
Dec. 1	....	0	25	40	30.5	Do.
Dec. 2	....	0	22	40	31.2	Do.
Dec. 3	....	0	11	26	17.9	Do.
Dec. 4	....	0	9	33	18.5	Do.
Dec. 5	....	0	15	32	24.0	Do.
Dec. 6	....	0	21	39	30.1	Rain.
Dec. 7	....	0	40	44	41.6	Do.
Dec. 8	....	0	32	40	36.2	Do.
Dec. 9	....	1	35	45	37.4	Do.

TABLE 7.—*Emergence of moths of the fall cankerworm, Wallingford, Conn., 1919 and 1920*—Continued.

IN 1920.

Date.	Emergence.		Temperature.			Remarks.
	Male.	Female.	Minimum.	Maximum.	Average.	
			°F.	°F.	°F.	
Oct. 28		1	52	67	60.2	Rain.
Oct. 29		0	39	53	46.5	Cloudy.
Oct. 30		0	36	49	42.0	Partly cloudy.
Oct. 31		2	39	65	52.3	Clear.
Nov. 1		0	43	64	52.8	Partly cloudy.
Nov. 2		0	40	63	52.0	Rain.
Nov. 3		0	43	62	51.1	Clear.
Nov. 4		1	35	57	46.7	Do.
Nov. 5		1	42	62	49.9	Do.
Nov. 6		1	40	56	46.0	Do.
Nov. 7		5	38	49	43.5	Rain.
Nov. 8		0	37	56	44.0	Do.
Nov. 9		1	35	59	50.3	Cloudy.
Nov. 10		2	33	58	47.2	Partly cloudy.
Nov. 11		0	29	43	34.8	Clear.
Nov. 12		0	25	44	33.1	Do.
Nov. 13		0	19	45	30.1	Do.
Nov. 14		0	22	45	32.1	Do.
Nov. 15		4	27	37	32.5	Light snow.
Nov. 16		0	34	38	35.8	Rain.
Nov. 17		1	36	46	39.5	Do.
Nov. 18		43	35	57	42.3	Clear.
Nov. 19		18	32	51	41.3	Do.
Nov. 20		15	37	51	42.8	Do.
Nov. 21		0	29	35	30.8	Light rain.
Nov. 22		5	32	41	36.0	Rain.
Nov. 23		14	37	48	41.8	Do.
Nov. 24		1	33	41	36.8	Rain and snow.
Nov. 25		0	31	33	32.7	Snow.
Nov. 26		1	28	42	32.2	Clear.
Nov. 27		10	30	39	34.9	Rain.
Nov. 28		9	31	36	34.9	Do.
Nov. 29		0	24	50	30.6	Clear.
Nov. 30		63	25	44	36.9	Cloudy.
Dec. 1		35	33	41	35.7	Rain.
Dec. 2	1	7	33	51	40.0	Partly cloudy.
Dec. 3		13	26	41	34.8	Clear.
Dec. 4		115	38	54	43.8	Rain.
Dec. 5		15	41	55	46.2	Do.
Dec. 6		1	34	42	39.3	Light rain.
Dec. 7		0	29	42	34.6	Partly cloudy.
Dec. 8		0	24	48	29.4	Clear.
Dec. 9		0	25	35	30.5	Partly cloudy.
Dec. 10		1	32	36	34.0	Do.

Upon emerging, the females make their way to the base of a near-by tree, and commence their ascent. If the weather is unfavorable—cold or rainy—the ascent may occupy several days. During especially cold periods, moths have been observed motionless in one spot on the trunk of a tree for 48 hours. Under ordinary conditions, however, their progress is much more rapid. The moths do not always reach a tree in their efforts to find a suitable place for oviposition, in such cases laying their eggs wherever they are able.

PROPORTION OF THE SEXES.

For some unexplained reason, all larvæ which were carried through in the insectary from egg to adult developed into female moths, and from field material, collected for the most part when the larvæ were in the last stage, only two males emerged in 1919 and

one male in 1920. In 1920 females were to be found in the field for 10 days before any males could be found. C. V. Riley, in his Seventh Report on the Insects of Missouri (*17*), noted that the females outnumbered the males, and the following year (*20*) stated that out of 58 reared specimens 56 were females. Other writers have mentioned this seeming preponderance of females, which is at present unexplained.

ACTIVITY OF THE MOTHS.

The greatest activity of the moths occurs just at dusk, although they continue to be more or less active during the night, and occasionally to a very limited extent during the daytime, especially if the day is dark and cloudy. During the day the moths are for the most part quiescent, the females often passing the time in the more or less protected places on the trunks of the trees. The winged male moths may pass the day in similar locations, and are also likely to be found in the grass and débris at the base of the tree.

With darkness a period of great activity begins if the weather is mild, and during this period mating usually takes place, although mated pairs are to be found throughout the night, and occasionally during the day. Moths *in coitu* have been observed at different times, but the male moths usually seem to pay comparatively little attention to females which have been fertilized and have been laying eggs.

PREOVIPOSITION PERIOD.

The length of time elapsing between the emergence of the female moth and the deposition of her eggs varies greatly, depending chiefly on weather conditions and upon whether the female has mated. During very cold weather the upward progress of the moth is very slow, and a number of days may elapse before egg-laying commences. Unfertilized females will lay only a very few scattered eggs. In 1920 a total of 20 females which emerged between October 28 and November 7 were placed in a wire cage in the insectary yard. November 10 one male was added, but apparently escaped or died, as it could not be found the following day. The day this male was placed in the cage a few scattered eggs were laid, but no more were found for more than a week. On the 18th six males were collected in the field and placed in the cage, and on the following day eight egg clusters were deposited. In this case the minimum preoviposition period was at least 12 days, oviposition evidently having been delayed pending the arrival of the males. On the other hand, a preoviposition period of slightly more than 24 hours has been noted in a number of instances, and under favorable conditions this period is usually less than three days.

Table 8 gives data in connection with the oviposition of 17 females isolated in battery jars in the insectary. Males were collected in the field, as none were available from the soil cages. It is not known why two of the moths (Nos. 3 and 17) delayed so long before laying their eggs. The average preoviposition period as calculated for these particular individuals has little significance, the length of this period being so very dependent on weather conditions, which are extremely variable in the late fall and early winter.

TABLE 8.—*Oviposition of individual moths of the fall cankerworm, Wallingford, Conn., 1920.*

Moth No.	Date female emerged.	Date male added.	Mated.	First eggs.	Last eggs.	Total masses.	Total eggs.	Preoviposition period.
								Days.
1	Nov. 18	Nov. 18	Nov. 19	Nov. 19	Nov. 20	2	169	1
2	...do...	...do...	...do...	...do...	Nov. 19	2	209	1
3	...do...	...do...	Nov. 20	Dec. 3	Dec. 4	2	310	15
4	...do...	...do...	Nov. 19	Nov. 19	Nov. 23	3	355	1
5	...do...	...do...	....	Nov. 20	Nov. 22	2	257	2
6	...do...	...do...	Nov. 19	Nov. 19	Nov. 19	2	261	1
7	...do...	...do...	...do...	...do...	...do...	1	237	1
8	...do...	Nov. 19	...do...	...do...	...do...	1	227	1
9	...do...	...do...	....	Nov. 20	Nov. 22	2	251	2
10	...do...	...do...	....	Nov. 19	Nov. 19	3	279	1
11	...do...	...do...	Nov. 19	...do...	Nov. 23	3	384	1
12	...do...	...do...	...do...	...do...	Nov. 28	7	277	1
13	...do...	...do...	...do...	...do...	Nov. 23	2	317	1
14	...do...	...do...	...do...	Nov. 20	Nov. 22	2	280	2
15	...do...	...do...	...do...	Nov. 19	Nov. 19	1	228	1
16	Nov. 19	...do...	Nov. 20	Nov. 20	Nov. 28	6	284	1
17	...do...	...do...	....	Dec. 15	Dec. 15	1	10	26
Total						42	4,335	....
Average per individual						2.5	255	3.5

WEATHER RECORDS.

Date.	Temperature.			Remarks.
	Minimum.	Maximum.	Average.	
	°F.	°F.	°F.	
Nov. 18	35	57	42.3	Clear.
Nov. 19	32	51	41.3	Do.
Nov. 20	37	51	42.8	Do.
Nov. 21	29	35	30.8	Light rain.
Nov. 22	32	41	36.0	Rain.
Nov. 23	37	48	41.8	Do.

OVIPOSITION.

Whenever possible, the moths usually make their way out to the smaller twigs before laying their eggs, although they sometimes deposit them on the trunk and larger branches, and will lay almost anywhere if they are unable to reach the places usually preferred for oviposition. Instances are on record of the oviposition of eggs on fence posts and on the sides of buildings. In captivity the moths often lay their eggs on the tops and sides of the cages instead of on the twigs provided for them. If halted by a barrier, they frequently place their eggs on the trunk beneath it.

Egg laying usually proceeds at a fairly rapid rate. Six of the moths noted in Table 8 emerged, mated, and laid their entire supply of more than 200 eggs each, within 48 hours. All except one moth (No. 17) disposed of all the eggs in their abdomens; for some reason this particular moth laid only 10 eggs, dying with 183 remaining in her abdomen. The eggs may be laid in one large mass, or divided among a number of smaller clusters.

LONGEVITY OF THE MOTHS.

In the protection of the rearing jars, some of the female moths lived a long time. Of the 17 females noted in Table 8, all lived more

than two weeks; one lived 32 days, and the average length of life was 27 days. Practically all eggs were laid during the first few days of confinement, and after this the moths were very sluggish and inactive. Under field conditions, the moths doubtless perish in a shorter time.

Males of a known date of emergence were not available, but those captured in the field and confined with the moths noted in Table 8 lived almost as long as the females, although it would hardly seem likely that the fragile-winged males would survive long under field conditions.

SPRING EMERGENCE.

It has been frequently recorded that the emergence of a few of the moths is often delayed until early spring. On March 26, 1920, one or two days after the frost had left the ground, a female moth, evidently recently emerged, was found in an orchard near the Wallingford laboratory. None emerged from the soil cages.

SPRING CANKERWORM.

DESCRIPTIONS.

EGG.

The eggs (Pl. III, A) are laid in crevices in the bark of the tree in loose clusters varying in number from a very few to more than 100. Quaintance (*32*) reported the number as varying from 17 to 119, with an average for 12 masses of 47. Counts by the present writers of 27 egg clusters, some of them laid in captivity and others collected in the field, showed a maximum of 75 eggs to the cluster, a minimum of 14, and an average of 34.5.

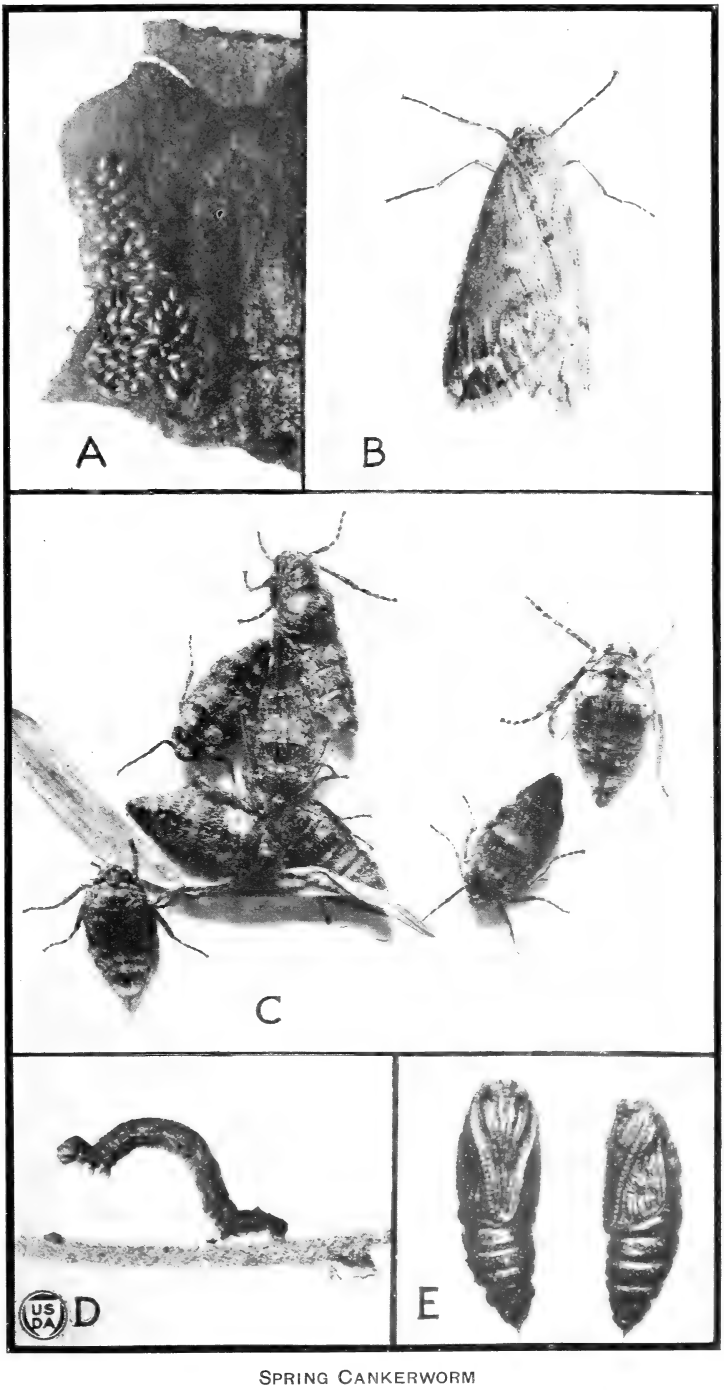
The egg cluster has no definite form, and the eggs may be either scattered or placed in a loose heap, somewhat stuck to each other and to the surface next to which they have been placed.

The individual egg is broadly oval in shape, one end being somewhat more broadly rounded than the other. The length varies from 0.66 to 0.85 millimeter, with an average of 0.77 millimeter; the width varies from 0.39 to 0.50 millimeter, averaging 0.45 millimeter. When first laid, the egg is a shining white, but in a few hours turns a light pearly yellowish brown with an iridescence giving purple and green reflections. The eggshell is thin with minutely sculptured longitudinal ridges.

LARVA.

First stage.—Width of head 0.25 to 0.28 millimeter, average 0.27 millimeter; length when newly hatched about 1.5 millimeters, when full-fed about 3.5 millimeters. General color dark olive green to black; head dull dark brown to black; dorsum with a central longitudinal interrupted dull white line, divided in the middle by a narrow, broken, olive-green line; each side with a lateral dull white line. Venter brownish olive-green; thoracic legs pale; prolegs, which are present on the sixth and anal segments, pale. Tubercles pale, tipped with darker color. Setæ short, pale yellow to white.

Second stage.—Width of head 0.41 to 0.50 millimeter, average 0.45 millimeter; length when full fed 5.5 to 6.5 millimeters. General color dark brownish olive-green, practically black in most cases; head dull black, whitish across clypeus, with additional light markings which vary from white to pale brown; dorsal surface with a median pair of narrow, broken, irregular white lines separated by a median olive-green line; along each side is a fairly broad, dull white line, more or less dotted with darker spots; between the lateral and dorsal lines just noted are sometimes faint suggestions of one or two narrow



SPRING CANKERWORM

A, Eggs on inner surface of a bit of bark (× 3½); B, male moth (× 2½); C, female moths (× 3½); D, partly grown larva (× 3); E, pupæ (× 4)

longitudinal lines, one of which nearly touches the broader lateral line; ventral surface not quite as dark as dorsal; thoracic legs concolorous with adjacent ventral surface; prolegs somewhat paler on inner side with darker areas on outer surface. Tubercles tipped with a dark spot; setæ short and dark: abdominal segment 8 somewhat enlarged dorsally.

Third stage.—Width of head 0.69 to 0.77 millimeter, average 0.73 millimeter; length when full fed 7.5 to 8 millimeters. General color variable, usually very dark olive-green to dull black with paler markings which vary in color from white to a dirty pale brown. Head brown to dull black with two irregular transverse pale mottled areas across lower portion of head, and additional mottlings of pale dirty brown to white; longitudinal lines of paler color much as described in previous instar; ventral surface slightly paler, with a pair of irregular, somewhat broken, paler median longitudinal lines on abdomen to prolegs; thoracic legs and prolegs about concolorous with adjacent surface; tubercles inconspicuous, tipped with a darker spot; setæ very minute. Eighth abdominal segment somewhat enlarged dorsally.

Fourth stage.—(Pl. III, D). Width of head 1.05 to 1.24 millimeters; average 1.12 millimeters; length when full fed 12 to 14 millimeters. General color very variable, from a reddish brown or olive green to black, with white to yellowish markings. Head dull black with white to yellow irregular mottlings; just below the middle of the head these markings form an almost solid transverse area; other parts of head irregularly marked, but the upper part mostly black. Dorsal surface with numerous narrow, irregular, broken, paler lines; a broad lateral area following the spiracles pale with numerous longitudinal darker markings; an adjacent area just dorsal to this often the darkest part of body; ventral abdominal surface with a broad longitudinal band of pale yellow to white, broadening out to nearly the width of the body from the sixth to anal segments; thoracic legs and prolegs concolorous with adjacent body color to somewhat paler. Tubercles small except for two large ones on the enlarged dorsal portion of the eighth abdominal segment; dark at center; setæ short, dark.

Many variations from the types described above occur. Some have a few to numerous dark spots on the dorsum and sides, especially on the second, third, and fourth abdominal segments.

Fifth stage.—Width of head 1.54 to 1.93 millimeters, average 1.72 millimeters: length when full grown 18 to 22 millimeters. Color and markings extremely variable; general color may be a reddish to a yellowish brown, a yellowish green, a dark blue-black, or any intermediate color. Head dirty white, mottled with brown, the relative proportions of each being variable, the upper half usually containing a greater amount of the darker color, with a dark line along the posterior edge of the head. Body lines irregular, varying in color from pale green or brownish yellow to white; just below the spiracles a well-defined, narrow, irregular pale line; from spiracles to center of dorsum are numerous lines, irregular, considerably broken, very numerous and distinct in some individuals, to some extent missing in others; usually the area between the two lines next above the spiracles is quite dark. Often the space between the lines just above and below the spiracles is fairly pale, the entire area forming a broad lateral longitudinal band. Ventral surface of abdomen with a broad longitudinal median line of pale yellowish green, which in many cases broadens out from the 6th to anal segment; central part of ventral surface of thorax green; thoracic legs paler than body, sometimes tinged with red in places; prolegs concolorous with body to paler; tubercles for the most part inconspicuous; two on dorsum of eighth abdominal segment raised, black in dark colored individuals and concolorous with body, except at bases of setæ, in lighter colored individuals. Setæ short, spiracles dark-margined. Behind abdominal spiracles are often swellings, each usually bearing an irregular black spot partially enclosing a smaller irregular spot of white.

Besides those already mentioned, numerous other irregular fine lines, dottings, and mottlings are found in many individuals.

PUPA.

Length 7 to 10 millimeters, not as stout as pupa of *Alsophila pometaria*. General color brown; wingpads greenish brown at first, turning brown later: surface pitted; last segment with a spine, which may be simple, or slightly forked at the end; abdominal spiracles somewhat raised, except those on eighth abdominal segment (Pl. III, E).

MOTH.

The following description has been condensed from Riley (*24*).

Male (Pl. III, B).—Wing expanse from 21 to 32 mm. Palpi very short, but distinctly two-jointed. Antennæ with not quite 40 joints, the longest twice as wide as long, each with two pairs of hair fascicles. Abdomen with first seven joints bearing each two transverse dorsal rows of stiff, reddish spines, pointed posteriorly. Wings delicate, silky, semitransparent, transversely striate, the scales short and very loosely attached. Upper surface of front wings brownish gray, crossed by three jagged, dark lines, sometimes obsolete except on the submedian and median veins, and on the costa, where they are always distinct and divide the wing into four subequal parts. A pale, jagged, subterminal band, corresponding in some degree to the outermost band in *A. pometeria*, but running out to apex, where it is always sharply relieved posteriorly by a dark mark, and often the whole length by dusky shadings. Hind wings pale ash or very light gray, with a dusky discal dot. No white band, and rarely any marginal dots. Under surface with a more or less distinct dusky spot on each wing, the front wing having in addition a dusky line along median vein and spot on costa towards apex. No pale bands.

Female (Plate III, C).—Length 5 to 9 mm. Antennæ generally with but few more than 30 joints, the longest about three times as long as wide, faintly constricted in middle, and pubescent. Body and legs pubescent, clothed with whitish and brown or black dentate scales or hairs; general coloration not uniform. Crest of prothorax and mesothorax black. A black stripe along the middle of the back of the abdomen, often interrupted on the 2d to the 7th segments, with a whitish patch each side of its front end. Abdomen tapering rather acutely behind. Two rows of spines on back of the first seven joints, more prominent than in the male, and often giving the dorsum a reddish aspect.

SEASONAL HISTORY AND HABITS.

EMERGENCE OF MOTHS.

The moths of the spring species emerge in early spring, very soon after the frost is out of the ground, and may occasionally leave the ground when warm periods occur during mild winters. Table 9 gives data concerning the emergence of moths in 1920 and 1921. Emergence in 1920 was from larvæ collected in various stages in the field the preceding spring and allowed to enter the ground normally. The 1921 records are partly from similar material, and partly from pupæ obtained from insectary material and later placed in the cages. Mortality was evidently high among the pupæ in the ground during the season of 1920–21, as evidenced by the extremely light emergence in the spring of 1921, when only 9 moths emerged from 157 larvæ and pupæ placed in the cages.

TABLE 9.—*Emergence of moths of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

IN 1920.

Date.	Emergence.		Temperature.			Remarks.
	Male.	Female.	Maximum.	Minimum.	Average.	
			°F.	°F.	°F.	
Mar. 27	1	....	58	39	46.4	Clear.
Mar. 28	....	....	64	35	47.3	Do.
Mar. 29	3	3	51	35	44.5	Rain.
Mar. 30	1	1	55	36	43.5	Clear.
Mar. 31	1	2	68	38	50.5	Do.
Apr. 1	2	....	57	36	44.5	Do.
Apr. 2	....	....	40	35	36.9	Rain.

TABLE 9.—*Emergence of moths of the spring cankerworm, Wallingford, Conn., 1920 and 1921*—Continued.

IN 1920—Continued.

Date.	Emergency.		Temperature.			Remarks
	Male.	Female.	Maximum	Minimum.	Average.	
			°F.	°F.	°F.	
Apr. 3	1	1	60	31	46.2	Clear.
Apr. 4	1	....	44	34	39.2	Rain.
Apr. 5	1	....	51	35	39.5	Do.
Apr. 6	....	....	38	30	33.5	Clear.
Apr. 7	2	....	45	30	36.0	Rain and snow.
Apr. 8	....	....	34	26	29.7	Clear.
Apr. 9	....	....	37	23	30.2	Cloudy.
Apr. 10	1	1	47	24	34.2	Clear.
Apr. 11	1	1	54	28	40.6	Do.
Apr. 12	2	....	49	30	41.8	Rain.
Apr. 13	2	1	51	35	45.1	Do.
Apr. 14	1	3	49	33	40.4	Clear.
Apr. 15	....	5	56	30	44.5	Do.
Apr. 16	....	....	48	38	43.1	Rain.
Apr. 17	....	....	48	39	41.8	Do.
Apr. 18	....	....	59	33	45.7	Clear.
Apr. 19	....	2	65	34	50.3	Do.
Apr. 20	....	....	71	41	54.2	Do.
Apr. 21	....	....	47	43	44.9	Rain.
Apr. 22	....	....	63	44	51.8	Clear.
Apr. 23	....	....	59	43	48.9	Rain.
Apr. 24	....	....	53	37	46.5	Clear.
Apr. 25	....	1	56	35	45.8	Do.
IN 1921.						
Mar. 17	1	2	52	....	....	Clear.
Mar. 18	....	....	40	25	35.6	Do.
Mar. 19	1	....	44	19	33.4	Do.
Mar. 20	1	....	74	43	56.4	Do.
Mar. 21	....	1	84	43	59.0	Rain.
Mar. 22	....	....	47	30	39.5	Clear.
Mar. 23	....	....	49	25	35.4	Do.
Mar. 24	....	2	48	27	39.0	Rain.
Mar. 25	....	....	68	49	57.2	Cloudy.
Mar. 26	....	....	67	42	51.8	Rain.
Mar. 27	....	....	69	51	56.2	Clear.
Mar. 28	....	....	70	34	51.4	Do.
Mar. 29	....	....	37	25	30.7	Do.
Mar. 30	....	....	44	20	32.9	Do.
Mar. 31	....	....	60	35	48.2	Rain.
Apr. 1	....	1	48	35	40.5	Do.

ACTIVITY OF THE MOTHS.

For the most part the habits of the moths are similar to those of the fall species. On leaving the ground the wingless females proceed to a near-by tree, slowly ascend the trunk, and make their way out to the smaller branches. The period of greatest activity occurs at dusk, and at this time mating usually occurs. During the day the moths are for the most part sluggish and inactive, usually passing the time under bark or concealed in other places, although the male moths are sometimes seen on the wing on cloudy or foggy days.

In from 2 to 6 days after emergence the female moths begin laying eggs, and may continue oviposition for as long a period as 10 days, although the greater part of the eggs are usually deposited during the first few days of oviposition. The moth lays the eggs in concealed places, to some extent on the main trunk, but for the most part on the smaller branches, and sometimes deposits them well out toward the tips of the twigs. In any event, they are hidden carefully

under flakes of bark, or in crevices or cracks, wherever such are found. The flexible and protrusible terminal segments of the abdomen are used as an ovipositor, which is capable of thrusting the eggs into very small crevices and quite a distance into the deeper and more extensive cavities. When placed under a bit of bark which has become somewhat loosened, the eggs are usually stuck to the inner surface of the bark, rather than to the outer surface of the wood from which it has separated. In some cases the eggs are placed in compact clusters; in others they are apparently thrust in at random. The greatest number of eggs laid by any female in captivity in the insectary at Wallingford was 250, which hardly represents the egg-laying capacity of the average moth. As the result of dissections, Wellhouse (*36*) records finding an average of 401 eggs each in the abdomens of 12 moths, and one of them contained 676 eggs.

In the protection of the insectary cages, most of the moths lived from one to two weeks, one female living 24 days. Under field conditions the length of life is probably not so great.

INCUBATION OF EGGS.

The incubation period varies to a considerable extent, the earliest laid eggs usually being subjected to cool weather which retards the development of the embryo larva. For this reason, hatching is likely to cover a shorter period of time than egg-laying. Table 10 gives data regarding incubation of eggs in 1920 and 1921.

TABLE 10.—*Incubation of eggs of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

IN 1920.

Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.	Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.
			Days.				*Days.*
Mar. 31	May 17	14	47	Apr. 15	May 20	26	35
Do	May 18	40	48	Do	May 22	1	37
Do	May 19	2	49	Apr. 21	May 21	14	30
Apr. 1	May 18	8	47	Do	May 22	42	31
Do	May 22	1	51	Do	May 23	37	32
Apr. 2	May 18	33	46	Do	May 24	11	33
Do	May 19	7	47	Apr. 22	May 22	3	30
Apr. 5	May 18	36	43	Do	May 23	15	31
Do	May 19	9	44	Do	May 24	28	32
Apr. 12	do	19	37	Do	May 25	7	33
Do	May 22	1	40				
Apr. 13	May 19	9	36	Maximum period			51
Do	May 20	25	37	Minimum period			30
Do	May 21	4	38	Average period			37.9
Apr. 15	May 19	24	34	Total individuals, 416.			

IN 1921.

Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.	Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.
Mar. 19	Apr. 24	2	36	Mar. 21	Apr. 28	2	38
Do	Apr. 25	5	37	Mar. 25	Apr. 27	6	33
Do	Apr. 26	4	38	Mar. 26	do	8	32
Do	Apr. 27	3	39	Do	Apr. 28	4	33
Do	May 2	1	44	Mar. 27	Apr. 23	1	27
Mar. 20	Apr. 22	1	33	Do	Apr. 24	2	28
Do	Apr. 23	7	34	Do	Apr. 25	13	29
Do	Apr. 24	78	35	Do	Apr. 26	2	30
Do	Apr. 25	105	36	Do	Apr. 27	2	31
Do	Apr. 26	5	37	Do	Apr. 28	94	32
Mar. 21	Apr. 25	11	35	Do	Apr. 29	9	33
Do	Apr. 26	13	36	Do	Apr. 30	1	34
Do	Apr. 27	1	37	Mar. 28	Apr. 28	32	31

TABLE 10.—*Incubation of eggs of the spring cankerworm, Wallingford, Conn., 1920 and 1921*—Continued.

IN 1921—Continued

Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.	Eggs laid—	Eggs hatched—	Number of eggs.	Incubation period.
			Days.				*Days.*
Mar. 28	Apr. 29	29	32	Apr. 3	Apr. 29	2	26
Do	Apr. 30	1	33	Do	Apr. 30	3	27
Do	May 1	1	34	Do	May 1	3	28
Mar. 31	Apr. 29	3	29	Do	May 2	1	29
Do	May 1	1	31	Apr. 4	...do...	5	28
Apr. 1	Apr. 28	1	27	Do	May 3	7	29
Do	Apr. 29	58	28	Apr. 5	May 6	3	31
Do	Apr. 30	1	29	Do	May 8	1	33
Apr. 2	Apr. 29	10	27				
Do	Apr. 30	4	28	Maximum period			44
Do	May 1	2	29	Minimum period			26
Do	May 2	1	30	Average period			32.7
Do	May 3	1	31	Total individuals, 550.			

TIME OF HATCHING OF THE EGGS.

The eggs of the spring cankerworm hatch at approximately the same time as those of the fall species. Just before hatching, the eggs turn dark, almost black. Table 11 gives hatching records for 38 egg masses collected in the field early in April, 1920, and for 19 egg masses laid in the insectary in 1921. The spring of 1920 was unusually late, while that of 1921 was equally early, giving a difference of about four weeks in the two seasons.

TABLE 11.—*Hatching of eggs of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

FROM 38 EGG MASSES COLLECTED IN THE FIELD IN 1920.

Date.	Number of eggs hatched.	Temperature.			Date.	Number of eggs hatched.	Temperature.		
		Maximum.	Minimum.	Average.			Maximum.	Minimum.	Average.
		° *F.*	° *F.*	° *F.*			° *F.*	° *F.*	° *F.*
May 14	30	54	45	48.7	May 20	70	76	51	61.1
May 15	58	64	46	54.8	May 21	3	59	53	56.0
May 16	205	71	43	58.1	May 22	21	66	48	55.2
May 17	217	74	47	60.6	May 23	10	58	46	51.3
May 18	78	71	46	58.0	May 24	4	66	47	53.2
May 19	59	75	45	58.8					

FROM 19 EGG MASSES LAID IN THE INSECTARY IN 1921.

Apr. 20	2	73	36	54.0	Apr. 30	10	58	49	53.8
Apr. 21	47	76	49	60.5	May 1	7	52	44	47.5
Apr. 22	10	78	49	60.9	May 2	8	68	42	52.4
Apr. 23	8	64	45	52.2	May 3	8	70	47	55.8
Apr. 24	82	67	42	54.3	May 4	....	64	48	54.8
Apr. 25	134	76	47	59.2	May 5	....	47	44	45.1
Apr. 26	24	73	44	57.6	May 6	3	49	45	47.0
Apr. 27	20	68	51	58.4	May 7	....	62	41	51.0
Apr. 28	133	73	56	64.0	May 8	1	73	45	56.9
Apr. 29	111	72	51	59.8					

LARVAL HABITS.

The habits of the spring cankerworm larvæ are very similar to those of the fall species. On hatching, the young caterpillars proceed to the unfolding foliage and feed here and there, at first eating the tissue on only one side of the leaf, leaving the portion opposite to die and turn brown. Soon the feeding extends through the leaf in the form of tiny punctures. The small worms often feed among the opening blossom buds. As the larvæ grow, the feeding areas increase in size, but the midribs and larger veins are left untouched, and have a frayed edge of ragged leaf tissue. When the infestation is light, the larvæ in their wandering distribute their feeding so that the injury is not conspicuous. When disturbed, the larvæ either spin down on threads or raise the anterior portion of the body, taking on the appearance of a short twig, or spur. When very small larvæ spin down on threads, they are often blown to an adjacent tree. When at rest, the larvæ of the spring cankerworm have a tendency to spend their time on a twig which they closely resemble in color, while the fall cankerworm larvæ, which are usually green, are much more likely to conceal themselves on a green shoot, or in the curl of a leaf.

NUMBER OF INSTARS.

All spring cankerworms under observation at Wallingford passed through five larval instars.

LARVAL FEEDING PERIOD.

Tables 12 and 13 give data relative to the larval feeding period for 96 larvæ during the season 1921. Table 14 gives the records of the average larval feeding period by instars for 1920 and 1921. The difference in the two seasons probably explains the difference in the feeding periods. The spring of 1920 was unusually late, but after the eggs had finally hatched, the weather was warm, and favorable to rapid larval development. On the other hand, the spring of 1921 was unusually early, causing an abnormally early hatching of the eggs, but the period immediately following hatching failed to continue as warm as it had been at the start. The average daily mean temperature during the larval feeding period in 1920 was 61.9° F., while that during the same period in 1921 was 57.9° F., an average difference of 4 degrees, which explains for the most part the longer feeding period in 1921.

TABLE 12.—*Length of larval feeding period of the spring cankerworm, Wallingford, Conn., 1921.*

Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.	Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.
Apr. 21	May 22	3	31	Apr. 24	May 24	1	30
Do	May 23	2	32	Do	May 25	3	31
Do	May 25	2	34	Do	May 26	1	32
Do	May 26	1	35	Do	May 27	1	33
Do	June 1	1	41	Do	May 28	3	34
Apr. 22	May 30	1	38	Do	May 29	1	35
Do	May 31	1	39	Do	May 30	1	36
Apr. 23	June 6	1	44	Do	May 31	2	37

TABLE 12.—*Length of larval feeding period of the spring cankerworm, Wallingford, Conn., 1921*—Continued.

Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.	Date of hatching.	Date entered ground.	Number of larvæ.	Number of days.
Apr. 24	June 4	1	41	Apr. 27	June 4	1	38
Apr. 25	May 26	1	31	Do	June 5	1	39
Do	May 27	2	32	Apr. 28	May 28	6	30
Do	May 28	1	33	Do	May 29	14	31
Do	May 29	4	34	Do	May 30	3	32
Do	May 30	3	35	Do	May 31	6	33
Do	May 31	2	36	Do	June 1	5	34
Do	June 1	1	37	Do	June 2	1	35
Do	June 5	2	41	Do	June 7	1	40
Do	June 6	1	42	Apr. 29	June 1	1	33
Apr. 26	May 29	1	33	Do	June 2	1	34
Do	May 30	2	34	Apr. 30	do	1	33
Do	June 4	1	39	May 1	May 30	1	29
Do	June 5	1	40	May 2	June 5	1	34
Apr. 27	May 30	1	33	May 3	June 2	1	30
Do	May 31	1	34	Do	June 3	1	31
Do	June 1	1	35				

TABLE 13.—*Length of larval feeding period of the spring cankerworm, Wallingford, Conn., 1921. Summary of Table 12.*

Number of days.	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.	Number of larvæ.
29	1	33	12	36	3	39	3	42	1
30	8	34	19	37	3	40	2	43	0
31	22	35	7	38	2	41	4	44	1
32	8								

Total larvæ, 96.
Average feeding period, 33.7 days.

TABLE 14.—*Larval feeding period of the spring cankerworm, by stages, Wallingford, Conn., 1920 and 1921.*

Stage.	1920		1921	
	Number of larvæ.	Number of days.	Number of larvæ.	Number of days.
First	252	7.75	196	9.87
Second	226	3.73	164	6.44
Third	201	3.66	139	5.19
Fourth	152	5.66	118	5.19
Fifth (to end of feeding)	158	5.31	96	6.80
Total feeding period		26.11		33.49

ENTERING THE GROUND.

As with the fall cankerworm, the larvæ enter the ground for pupation to a depth varying from one to several inches. Only a few threads of silk are spun in the pupal cell, and no cocoon is formed. Table 15 gives the dates on which the larvæ were entering the ground in 1920 and 1921.

TABLE 15.—*Entrance into ground of larvæ of the spring cankerworm, Wallingford, Conn., 1920 and 1921.*

1920 Date.	1920 Number of larvæ.	1920 Date.	1920 Number of larvæ.	1921 Date.	1921 Number of larvæ.	1921 Date.	1921 Number of larvæ.	1921 Date.	1921 Number of larvæ.
June 10....	2	June 17....	9	May 22....	3	May 29....	20	June 5.....	5
June 11....	3	June 18....	1	May 23....	2	May 30....	12	June 6.....	2
June 12....	25	June 19....	0	May 24....	1	May 31....	12	June 7.....	1
June 13....	47	June 20....	2	May 25....	5	June 1.....	9		
June 14....	23			May 26....	3	June 2.....	4	Total....	96
June 15....	16	Total....	158	May 27....	3	June 3.....	1		
June 16....	30			May 28....	10	June 4.....	3		

PREPUPAL PERIOD.

The time elapsing between the entrance of the larva into the ground and pupation has varied from 4 to 12 days, with an average period of 6.68 days in 1920 and 7.03 days in 1921.

NATURAL CONTROL.

One outstanding feature of cankerworm history is the recurrence of extremes of abundance and scarcity. In many cases the periods of extreme abundance have been suddenly terminated by an almost total disappearance of the worms, followed by a period of comparative freedom from attack. In his original account Peck (*2*) records an almost complete disappearance of the worms between 1794 and 1795. One of the early agricultural papers notes that the worms "run out in three years." Unfortunately many of the outbreaks have not "run out" at the end of 3 years, but have increased in severity for as long as 8 or 10 years before natural causes have put an end to them, for the time being at least. During the periods of scarcity, the worms usually increase in numbers more or less steadily, although for the most part unobserved, until they again appear in great numbers.

The records are frequently obscured by accounts of outbreaks of a local nature independent of the general waves of abundance and scarcity. The records of outbreaks previous to 1875 are especially hard to interpret owing to the confusion of the two species, making it difficult to tell whether successive outbreaks consisted of the same or of different species.

A detailed discussion of the various factors connected with the natural control of the cankerworm follows.

WEATHER CONDITIONS.

Weather conditions have often been given the credit for the sudden disappearance of the cankerworms. Peck (*2*) noted that the 17th of May, 1794, was so cold that ice one-third of an inch thick was produced. This temperature was apparently fatal to the larvæ, with the result that practically no moths could be found the following year. This freeze evidently occurred just after all the larvæ had hatched. In a communication to the New England Farmer

dated June 7, 1826, Roland Howard (*7*) relates that after a period of abundance from 1806 to 1809, practically no worms were present in 1810, which was attributed by some to a severe storm soon after the worms had hatched. It seems likely that either cold, stormy weather, or extreme cold unaccompanied by rain, especially if this occurs soon after the larvæ have hatched, may be fatal to them.

Wet weather also favors the development of wilt diseases, but these do not seem to have been at any time prevalent enough to account for the sudden disappearance of the cankerworms.

DISEASES.

Peck noted that some of the larvæ were attacked by a disease which he called "deliquium," evidently referring to one of the wilt diseases which commonly attack lepidopterous larvæ. Wellhouse (*36*) records finding a wilt disease killing some larvæ of the spring cankerworm in Kansas. Sherman (*39*), reporting on a severe outbreak of the fall species in the mountains of North Carolina, which had been in progress for four seasons, stated that fungous and bacterial diseases were not much in evidence "although warm and damp weather was not lacking. Only an occasional worm was found which seemed to have perished from disease, and there was no hint of an epidemic among them." Under crowded conditions and in the confined air of some of the rearing cages used for miscellaneous material in the insectary at Wallingford, a very few larvæ were attacked by some form of "wilt" disease, but no infected larvæ were found under field conditions. The cankerworms do not seem to be as subject to wilt diseases as are many caterpillars, especially the colonial forms.

STARVATION.

In a letter to the Western Rural of June 23, 1866, Sanford Howard (*12*), secretary of the Michigan Board of Agriculture, suggested among other things that the cankerworm may have been present in such numbers that the available foliage was not sufficient to carry them to maturity. It seems entirely conceivable that under certain conditions the larvæ might be numerous enough to exhaust all available foliage by the time they were only partially grown. In such a case very few larvæ would be successful in reaching maturity, and the infestation would be greatly reduced the following season. Naturally, starvation in this manner could occur only where the cankerworms were exceptionally abundant.

BIRDS.

Because the cankerworm larvæ feed in exposed locations, and are not protected by hairs or other repellent devices, they are a favorite food with many of our common birds. Work done by Forbes (*22*) in Illinois indicated that when the cankerworms became unusually abundant, many different species of birds ate enormous numbers of them. Chickadees have been found with large numbers of the eggs of the fall cankerworms in their crops (*28*). Even specimens of the much-despised English sparrow have been found with their crops full of cankerworm larvæ. Practically all of our common birds have been recorded at one time or another as cankerworm feeders,

and no attempt will be made to present a complete list. Besides feeding on the larvæ, such birds as are present in the late fall and early spring prey upon the moths as they emerge and make their way up the trees. Birds seem to be among the most important of the enemies of the cankerworms.

INSECT ENEMIES.

PREDATORS.

The following beetles have been recorded as feeding on cankerworm larvæ: *Calosoma willcoxi* Lec., *C. frigidum* Kirby, *C. calidum* Fab., and *C. scrutator* Fab. In addition, Forbes (*23*) found spring cankerworm remains in the intestinal tracts of the following carabid beetles in Illinois: *Galerita janus* Fab., *Calathus gregarius* Say, *Evarthrus sodalis* Lec., *Chlaenius diffinis* Chd., *Harpalus caliginosus* Fab., and *Harpalus pennsylvanicus* De Geer. The pentatomid bug *Podisus modestus* Dall., a mirid (*Lygus* sp.), two species of ants, a species of Panorpa, and the rapacious soldier-bug (*Sinea diadema* Fab.) have all been recorded as feeding on cankerworm larvæ.

The fraternal potter-wasp (*Eumenes fraternus* Say) has been known to store her nest with 20 cankerworm larvæ (*14*).

This list of predators could doubtless be extended to include many other predacious insects, particularly those having general feeding habits, which probably do not refuse any cankerworms they may chance to find.

PARASITES.

A number of insect parasites of the cankerworms have been recorded. In the vicinity of Wallingford, Conn., neither species has been very severely parasitized, although several different parasites have been reared in small numbers. The recorded parasites of both species of cankerworms are noted below, together with a few observations made at Wallingford.

Telenomus gnophaelae Ashm.—This was recorded by Girault (*31*) as a parasite of the eggs of the fall cankerworm. A. B. Gahan, of the Bureau of Entomology, however, has expressed some doubts as to the correctness of this determination, as none of the specimens which he has had from cankerworm eggs agree with Ashmead's type of *gnophaelae*.

Telenomus sp.—In 1919, 80 adults of a species of Telenomus emerged from 2 of 32 fall cankerworm egg masses under observation at Wallingford. The following year no egg parasites were reared. Sherman (*39*) reports that a species of Telenomus has been reared in numbers from eggs of the fall cankerworm in the mountainous regions of North Carolina.

Platygaster sp.—In 1840 Herrick (*8*) reared a species of egg parasite in considerable numbers from the eggs of the fall cankerworm, and expressed the opinion that it belonged to the genus Platygaster. As far as can be determined, no parasite of the eggs of the fall cankerworm since reared has been referred to that genus, and A. B. Gahan states that there can be little doubt that what Herrick had was in reality a Telenomus.

Meteorus hyphantriae Riley.—A few cocoons of *Meteorus hyphantriae* were found in trays containing nearly full-grown larvæ of the

fall and spring species, respectively, collected near Wallingford during the spring of 1919.

Rogas sp.—Occasionally third-instar larvæ of the fall cankerworm were found near Wallingford parasitized by a species of Rogas, their dried and shrunken skins serving as shelters for the parasite pupæ. Harrington (*25*) reports finding a number of larvæ in a similar condition, but all were infested with secondary parasites, determined as *Hemiteles sessilis* Prov.

Euplectrus sp.—One third-instar fall cankerworm larva was found near Wallingford on June 5, 1919, collapsed and doubled over a greenish parasite larva which was constructing its cocoon. The adult parasite emerged two weeks later. Payne (*37*) reports from Nova Scotia the rearing of a species of Euplectrus, and Sherman (*39*) also reports a species of the same genus from the fall cankerworm from North Carolina. Both of these may be the same and identical with the parasite reared at Wallingford.

Amblyteles utilis Cresson.—*Amblyteles utilis* has been recorded as a parasite of cankerworms (*35, p. 359*).

Apanteles paleacritae Riley.—This species was described by Riley (*21*) as a parasite of the spring cankerworm and reported by Harrington from the fall species. A single adult of this species was reared by Dwight Isely, of the Bureau of Entomology, in May, 1918, at Bentonville, Ark., from a larva of the spring cankerworm. It is said that the host larva does not die until some time after the emergence of the parasite larva, which spins its cocoon on its host or a near-by leaf.

Tachinomyia sp.—Fourth-stage and sometimes third-stage larvæ of the fall cankerworm are sometimes found bearing on the head or prothorax one or more oval, flattened, creamy white tachinid eggs. On hatching, if the host larva has not molted in the meantime, the parasite larva makes its way through the skin of the caterpillar, usually on or near the head, and takes up its position just beneath. Parasitized larvæ complete their development, enter the ground, and commence the construction of their cocoons, but rarely complete them before being killed by the parasite. Out of five parasitized larvæ entering the ground at Wallingford in the spring of 1919, two flies emerged in May, 1920. These were determined by Dr. J. M. Aldrich as a species of Tachinomyia, probably undescribed.

Harris (*9*) mentioned a tachinid fly as a parasite of the cankerworm in Massachusetts, causing a mortality of one-third. Many other workers have mentioned tachinid parasites, but none seem to have been reared and determined.

Sarcophaga cimbicis Townsend or *S. latisterna* Parker.—This species was reared by Sherman from the fall cankerworm in North Carolina in 1920, and determined by Dr. J. M. Aldrich.

OTHER ENEMIES.

Coriarachne versicolor Keyserling.—Spiders determined by C. R. Shoemaker, as this species were found near Wallingford feeding on the spring cankerworm moths as they emerged.

Nothrus ovivorus Packard.—This mite was described by Packard (*13, p. 664, fig. 639*) and recorded as having been observed in the act of sucking the eggs of the fall cankerworm. As far as is known, this

initial observation has never been verified. Dr. H. E. Ewing, of the Bureau of Entomology, states that this species is unrecognized, and that the habit of sucking eggs, if it occurs, is contrary to the habits of the group to which the genus Nothrus belongs.

CONTROL MEASURES.

Three general methods have been recommended and used for the control of cankerworms: Cultivation, spraying, and the use of mechanical barriers to prevent the ascent of the wingless female moths and the larvæ.

CULTIVATION

Plowing and cultivation at any time when the spring cankerworm larvæ or pupæ are in the ground will aid materially in their control by exposing them to many of their enemies. This practice, however, will have little effect on the fall species, which is safely inclosed in a tough cocoon.

SPRAYING.

The present practice of spraying for the codling moth and other insects has almost eliminated the cankerworm as a pest in well-cared-for orchards.

Laboratory tests have shown that the larvæ of both species are readily killed by arsenate of lead, applied at the strength of 1 pound of the powdered form in 50 gallons of water. In all tests made in the laboratory at Wallingford, even the last-stage larvæ died within four or five days after being placed on sprayed foliage, and the earlier stages were killed in a shorter time.

Although the larval feeding period of the cankerworms is short, it occurs at such a time that the first two of the regular summer spray applications recommended for the apple orchard will be effective. Peck (*4*) noted that the eggs "commonly hatched about the time that the red currant is in blossom, and the apple tree puts forth its tender leaves." In Wallingford the greater part of the hatching of the eggs of the fall species has invariably occurred during the period when the apple blossoms of medium-season varieties were showing pink, and was practically completed before the blossoms were open. The eggs of the spring species began to hatch in 1920 a day or two later than those of the fall species, and the hatching period was somewhat more prolonged. It is therefore evident that if the so-called pink spray includes an arsenical, and is thoroughly applied, the newly hatched larvæ of both species will find awaiting them a meal of poison. This application is the more important of the two noted, and in case of a severe infestation should never be omitted. If an outbreak occurs in young orchards not in bearing, an application of arsenate of lead should be made shortly after the proper time for the pink spray on bearing trees, at which time all the eggs will have hatched, but comparatively little feding will have been done. Observations in an orchard near Wallingford during the season of 1920 confirmed these recommendations. The orchard in question had been totally neglected for a number of years, and had become thoroughly infested with the spring cankerworm. In 1920 the owners applied the pink spray, but were a few days late about it, al-

though it was completed before the blossoms had opened to any extent. Before the spraying was done practically every leaf was being eaten by several larvæ. A few days later it was difficult to find a living larva, and practically impossible to find a healthy one.

Quaintance (*32*) has reported almost perfect control of the spring cankerworm in two orchards in Virginia. In 1905 a single application of Paris green at the rate of 1 pound in 75 gallons of water, applied when the larvæ were one-half to two-thirds grown, caused an almost complete disappearance of the larvæ within three days. The following year part of a second orchard was sprayed twice with arsenate of lead with similar results.

No field tests were made at Wallingford with the fall species, but results equally satisfactory could doubtless be obtained.

In orchards which are well cared for, the cankerworm infestation is seldom severe, and can usually be sufficiently controlled by the calyx spray. This application is ordinarily put on about as the larvæ of both species are entering the fourth stage, and have at least 8 to 10 days yet to feed. During this time most of the larvæ present will be killed. This application alone will keep a light infestation within bounds, although it will not prevent much of the injury of the season when the application is made.

Where spraying is consistently practiced there is little complaint of cankerworm damage. In properly sprayed orchards banding and other measures for cankerworm control are seldom necessary.

MECHANICAL BARRIERS.

When for any reason spraying is impracticable, the use of various mechanical barriers, properly applied, will give complete protection. At a very early date the wingless condition of the female moths was recognized as a weak point in the life history of the cankerworm, and a number of interesting and ingenious types of barriers were devised and used in the effort to prevent the moths from ascending the trees to lay their eggs. At present the most common method of preventing the ascent of the moths is by means of sticky bands. For applying any of the commercial tree-banding materials, Doctor Britton (*33*), of the Connecticut Experiment Station, recommends the following procedure: First, place around the trunk of the tree a strip of cotton batting 2 or 3 inches wide; second, cover this with a band of tarred paper 5 or 6 inches wide, drawing it tight and tacking it at the ends, which should overlap; finally apply a smooth coat of sticky material one-eighth of an inch thick and covering about two-thirds of the width of the tarred paper. The cotton batting serves to fill any irregularities in the bark and prevents the passage of the moths under the tarred paper. The use of the tarred paper makes possible a more economical use of the sticky material than would be possible in applying it directly to the rough and irregular bark, and eliminates possible injury to the tree.

Directions for making a gipsy moth tree-banding material which has been developed at the gipsy moth laboratory at Melrose Highlands, Mass., are as follows (*38*):

Prepare a stock mixture by placing in a large kettle one part by weight of hard coal-tar pitch [melting point about 49° C.] and adding one part by

weight of coal-tar neutral oil [density of 1.12 to 1.15 at 20° C.], applying heat to the kettle until all of the pitch has melted and thoroughly mixed with the oil, then removing the kettle and adding two more parts by weight of coal-tar neutral oil and mixing the contents thoroughly. This product, known as pitch neutral-oil mixture, can be poured and worked after cooling.

The banding material is mixed as follows:

Eighteen pounds of the pitch neutral oil or stock mixture and 70 pounds of the coal-tar neutral oil are added to the mixing kettle and the stirrer started working. In a few moments 12 pounds of hydrated lime are added slowly to the mixture. When the contents have become of a uniform consistency 50 pounds of rosin oil [known as first run "kidney," having a viscosity of 52 at 100° C. tested with a Saybolt universal viscosimeter] are added and allowed to mix for a few minutes, or until the contents begin to thicken, after which 20 pounds of coal-tar neutral oil are added and the contents allowed to mix thoroughly. The stirring is then stopped and the material poured into containers and allowed to set for two or three days, and by the end of this time the material has set into a semisolid state, of somewhat softer consistency than cup grease.

For use in the cooler seasons of cankerworm emergence, the formula should be modified by the addition of a little more of the coal-tar neutral oil.

This material may be applied with a putty knife or a thin hardwood paddle directly to the tree, after first removing any loose flakes of bark. It has proved fairly effective against the cankerworm moths except in extremely heavy emergences, in which cases bands 6 inches wide were bridged and crossed in a very short time. For the cankerworm moths the most satisfactory band is one rather thin and several inches wide, rather than the narrower bands which are applied for the gipsy moth with a special gun.

The bands should be examined at intervals, particularly during the period when the moths will be likely to emerge in greatest numbers, and the surface renewed by stirring with a putty knife or paddle whenever it has been bridged by foreign matter or the bodies of moths, which, when numerous, will sometimes bridge a fairly broad band, enabling the moths emerging later to pass without becoming entangled. One may determine whether the bands are doing effective work by the use of a check band, placed above the first on a tree here and there. Some of the moths on reaching the obstruction will not attempt to pass, but will lay their eggs below it. For this reason, the band should remain effective until apple-blossom time is over in order to protect the foliage from the larvæ hatching from such eggs. In severe infestations it will pay to continue the barriers another month for the purpose of preventing the reascent of any larvæ which have dropped from the tree.

Barriers of wire, tin, or lead were formerly used to quite an extent, but they are hard to fit perfectly to the irregular surface of the tree trunk, and do not always prevent the passage of larvæ hatching from eggs laid below them. Barriers of cotton batting and other loose, fluffy material are sometimes used, but are likely to become matted down by rain, and are not on the whole as satisfactory as the sticky bands.

For the control of the fall species the bands should be in place at least by the middle of October, and remain effective until the ground is thoroughly frozen for the winter. With severe infestations they should be renewed as soon as the ground thaws with the first warm days of late winter or early spring, in order to intercept any moths whose emergence has been delayed. They should be kept effective

until the apple blossoms have fallen, when all eggs laid below them will have hatched.

For the spring species the barriers should be in place with the first thawing of the ground in February or March, and remain effective until after the apple blossoms have fallen, as indicated for the fall species.

SUMMARY.

The cankerworms have been known in this country since colonial days, but not until about 50 years ago was it realized that two species were present. They have since been known as the fall cankerworm (now *Alsophila pometaria* Harris) and the spring cankerworm (*Paleacrita vernata* Peck).

The cankerworms prefer to feed on elm and apple, but are often found on many of our common deciduous fruit, forest, and ornamental trees.

The fall cankerworm is found in greatest abundance in the northeastern part of the United States and the southeastern part of Canada, but has been reported from several of the States in the Mississippi Valley, from Colorado, and from California. The spring species is found in southern Canada as far west as Manitoba, in the northeastern and central portions of the United States as far south as Texas, and in California.

As the females are wingless, dissemination by their own efforts is slow. The larvæ of both species are sometimes caught on passing vehicles and carried to new localities. The eggs of both species, and particularly those of the fall species, are likely to be carried to new localities on nursery stock.

During periods of abundance the cankerworms do an enormous amount of damage, practically defoliating the trees they attack unless controlled. They are most likely to become abundant in neglected orchards or in shade and forest trees.

Both species have but one generation a year.

The moths of the fall cankerworm emerge from the ground mostly in late fall and early winter during warm periods after the ground has been frozen. Mating and egg laying soon occur, and the species winters in the egg stage, except in occasional instances in which the emergence of the moths is delayed until spring. The eggs hatch in the spring, during the period when the apple blossoms are in the pink. The larvæ feed for four to five weeks, passing through four stages. When through feeding they enter the ground, construct a tough cocoon, and after about a month transform to the pupa.

The spring cankerworm moths emerge almost exclusively in the spring, and lay eggs in the crevices of the bark and in similar protected locations. The hatching of the eggs and the larval feeding period coincide rather closely with those of the fall species, but the spring cankerworm passes through five larval stages. No cocoon is constructed, and pupation occurs soon after the larva has entered the ground.

The two species are readily distinguished in all stages.

The cankerworms are held in fluctuating degrees of control by an extensive array of factors, among which are unfavorable weather, birds, and parasitic and predacious insects.

Plowing during the summer and fall will aid in the control of the spring cankerworm. Both species are readily controlled by a *thorough* application of arsenate of lead in the so-called pink spray, with a second application soon after the apple blossoms have fallen. Where spraying is impracticable, satisfactory control may be obtained by the use of barriers at the proper time to prevent the ascent of the moths, and later that of the larvæ hatching from eggs laid beneath the barriers.

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